Version 2

ARMY
24.B Small Business Technology Transfer (STTR)
PROPOSAL SUBMISSION INSTRUCTIONS

The approved 24.B Broad Agency Announcement (BAA) topics for the Army Small Business Technology Transfer (STTR) Program are listed below. Offerors responding to this BAA must follow all general instructions provided in the Department of Defense (DoD) Program BAA. Specific Army STTR requirements that add to or deviate from the DoD Program BAA instructions provided in the Preface are provided below.

The STTR Program Management Office (PMO), located at the Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) Army Research Office (ARO), manages the Army's STTR Program. The Army STTR Program aims to stimulate a partnership of ideas and technologies between innovative small business concerns (SBCs) and research institutions (RIs) through Federally-funded research or research and development (R/R&D). To address Army needs and opportunities, the PMO relies on the vision and insight of science and engineering workforce across eight (8) participating Army organizations to put forward topics that are consistent with their mission, as well as command and STTR program goals. More information about the Army STTR Program can be found at https://www.armysbir.army.mil.

See DoD Program Announcement Preface for Technical questions and Topic Author communications. Specific questions pertaining to the Army STTR Program should be submitted to:

Army STTR Program Manager
usarmy.rtp.devcom-arl.mbx.sttr-pmo@army.mil

DEVCOM-ARL-Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709
(919) 549-4200

In addition to the formal announcement period, the Army STTR Program Office will be hosting virtual Army STTR Industry Days on 24-25 April 2024 to further delineate Army requirements, provide opportunity for interested parties to engage topic authors, and enable small business/research institute partnership-building to expand participation. Please visit: www.armysttr.com for more information.

Proposers 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.
- Register for the DSIP Listserv at: https://www.dodsbirsttr.mil/submissions/login.

PHASE I PROPOSAL GUIDELINES

Phase I proposals should address the feasibility of a solution to the topic. The Army anticipates funding two (2) STTR Phase I contracts to small businesses with their research institution partner for each topic. The Army reserves the right to not fund a topic if the proposals received have insufficient merit. Phase I contracts are limited to a maximum of $204,000.00 over a period not to exceed six (6) months. **PLEASE NOTE THAT THE MAXIMUM DOLLAR AMOUNT HAS BEEN INCREASED COMPARED TO PREVIOUS PHASE I's**. Army STTR uses only government employee reviewers in a two-tiered review process unless otherwise noted within the topic write-up. Awards will be made on the basis of technical evaluations using the criteria described in this DoD BAA Preface and availability of Army STTR funds.

The DoD SBIR/STTR Proposal Submission system (https://www.dodsbirsttr.mil/submissions/login) provides instruction and a tutorial for preparation and submission of your proposal. Refer to DoD BAA Preface for detailed instructions on Phase I proposal format. The Company Commercialization Report (CCR) must be uploaded in accordance with the instructions provided in the DoD Program BAA. Information contained in the CCR during will be considered during proposal evaluations.

The Army requires your entire proposal to be submitted electronically through the DoD-wide SBIR/STTR Proposal Submission Web site (https://www.dodsbirsttr.mil/submissions/login). STTR Proposals consist of six required volumes: (1) Proposal Cover Sheet, (2) Technical Volume, (3) Cost Volume, (4) Company Commercialization Report (CCR), (5) Supporting Documents, and (6) Fraud, Waste, and Abuse Training. Proposals not conforming to the terms of this BAA will not be considered for evaluation nor award.

The Army has established a **10-page limitation** for Technical Volume, Volume 2, submitted in response to its topics. This does not include the Proposal Cover Sheets (pages 1 and 2, added electronically by the DoD submission site), the Cost Volume, Volume 3, or the CCR, Volume 4. The Technical Volume, Volume 2, includes but is not limited to: technical approach and objectives, key personnel background and qualifications, facility information, the relationship of the proposed work to any prior, current, or pending support of similar proposals or awards, commercialization strategy, references and letters of support, appendices, and all attachments.

The Army requires that small businesses complete the Cost Volume form on the DoD Submission site versus submitting it within the body of the uploaded Technical Volume. It is the responsibility of submitters to ensure that the Technical Volume, portion of the proposal does not exceed the 10-page limit. Do not include blank pages, duplicate the electronically generated cover pages, or put information normally associated with the Technical Volume such as descriptions of capability or intent in other sections of the proposal, as these will all count toward the 10-page limit.

Army STTR Phase I proposals submitted containing a Technical Volume over 10 pages will be deemed NON-COMPLIANT and will not be evaluated nor considered for award. It is the responsibility of the Small Business to ensure that once the proposal is submitted and uploaded into the system, that the technical volume .pdf document complies with the 10-page limit. If you experience problems uploading a proposal, email DSIP Support at DoDSBIRSupport@reisystems.com.

Companies should plan carefully for research involving animal or human subjects, biological agents, etc. as noted in the DoD BAA Preface. The short duration of a Phase I effort may preclude plans including these elements unless coordinated before a contract is awarded.

If the offeror proposes to employ a foreign national, refer to the DoD BAA Preface for definitions and reporting requirements. Please ensure no Privacy Act information is included in this submittal.

If a small business concern is selected for a STTR award, they must negotiate a written agreement between the small business and their selected research institution that allocates intellectual property rights and rights to carry out follow-on research, development, or commercialization (see DoD BAA Preface for more information).

PHASE II PROPOSAL GUIDELINES

All Phase I awardees may apply for a Phase II award for their topic – i.e., no invitation required. Please note that Phase II selections are based, in large part, on the success of the Phase I effort, so it is vital for SBCs to discuss the Phase I project results with their Army Technical Point of Contact (TPOC). Army STTR does not currently offer a Direct-to-Phase II option. Each year the Army STTR Program Office will post Phase II submission dates, 30-day window, on the Army SBIR/STTR web page at https://www.armysbir.army.mil/phase/. The details on the due date, content, and submission requirements of the Phase II proposal will be provided by the Army STTR PMO via subsequent notification of Phase I awardees. The SBC may submit a Phase II proposal for up to three years after the Phase I selection date, but not more than twice. The Army STTR Program *cannot* accept proposals outside the Phase II submission dates established. Proposals received by the DoD at any time other than the submission period will not be evaluated.

Phase II proposals will be evaluated for overall merit based upon the criteria in the DoD BAA Preface of this BAA. STTR Phase II proposals have six required Volumes: (1) Proposal Cover Sheet, (2) Technical Volume, (3) Cost Volume, (4) Company Commercialization Report (CCR), (5) Supporting Documents, and (6) Fraud, Waste, and Abuse Training. The Technical Volume has a **20-page limit** including: table of contents, pages intentionally left blank, technical references, letters of support, appendices, technical portions of subcontract documents (e.g., statements of work and resumes), and any attachments. However, offerors are instructed to NOT leave blank pages, duplicate the electronically generated cover pages, or put information normally associated with the Technical Volume in others sections of the proposal submission as these will count toward the 20-page limit. ONLY the electronically generated Cover Sheets, Cost Volume, and CCR are **excluded** from the 20-page limit. As instructed in the DoD BAA Preface, the CCR is generated by the submission website based on information provided by you through the "Company Commercialization Report" tool. **Army STTR Phase II proposals submitted containing a Technical Volume over 20 pages will be deemed NON-COMPLIANT and will not be evaluated nor considered for award.**

Small businesses submitting a proposal are also required to develop and submit a technology transition and commercialization plan describing feasible approaches for transitioning and/or commercializing the developed technology in their Phase II proposal.

Army Phase II Cost Volumes must contain a budget for the entire 24-month period not to exceed the maximum dollar amount of $1,363,000.00. **PLEASE NOTE THAT THE MAXIMUM DOLLAR AMOUNT HAS BEEN INCREASED COMPARED TO PREVIOUS PHASE II's**. Costs for each year of effort must be submitted using the Cost Volume format (accessible electronically on the DoD submission site). The total proposed amount should be indicated on the Proposal Cover Sheet as the Proposed Cost. Phase II projects will be evaluated after the base year prior to extending funding for the option year. Phase II proposals are generally structured as follows: the first 12 months (base effort) should be approximately $681,500.00; the second 12 months of funding should also be approximately $681,500.00. The entire Phase II effort should not exceed $1,363,000.00. The Phase II contract structure is at the discretion of the Army's Contracting Officer, and the PMO reserves the option to reduce an annual budget request of greater than $681,000.00 if program funds are limited.

Any Sequential Phase II proposal (i.e., a second Phase II subsequent to the initial Phase II effort) shall be initiated by the Government Technical Point of Contact for the initial Phase II effort and must be approved by Army STTR PM in advance.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA)

In accordance with section 9(q) of the Small Business Act (15 U.S.C. 638(q)), offerors are encouraged to request technical and business assistance. The objective of this effort is to increase Army STTR technology transition and commercialization success thereby accelerating the fielding of capabilities to Soldiers and to benefit the nation through stimulated technological innovation, improved manufacturing capability, and increased competition, productivity, and economic growth. Details related to TABA are described in the DoD STTR Program BAA. All such requests must be made in accordance with these instructions. TABA may be proposed in the Base and/or Option periods, but the total value may not exceed $6,500 in Phase I and $25,000 per year in Phase II (for a total of $50,000 for two years). All details of the TABA agency and what services they will provide must be listed in the technical proposal under "Consultants." **The request for TABA must be included in Volume 2 under the Consultants subsection and include details on what qualifies the TABA firm to provide the services that you are requesting, the firm name, a point of contact for the firm (email address and phone number), and a website for the firm. The requested TABA amount must be noted in Volume 3. List all services that the firm will provide and why they are uniquely qualified to provide these services.** The award of TABA funds is not automatic and must be approved by the Army STTR Program Manager.

NOTIFICATION SCHEDULE OF PROPOSAL STATUS AND TECHNICAL EVALUATION FEEDBACK

Once the selection process is complete, an email will be sent to the "Corporate Official" listed on the Proposal Coversheet with a link to the Army STTR Small Business Portal, notifying firms of their proposal's change of status. In the portal, a letter signed by the Army STTR Program Manager indicating selection or non-selection will be available with instructions on how to request a Technical Evaluation Feedback. Small Businesses will receive a notification email for each proposal submitted. The Army STTR Program Manager and/or the Organization's Program Coordinator will provide ***written*** Technical Evaluation Feedback at the request of the offeror.

PROTEST PROCEDURES

Refer to the DoD Program Announcement 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: usarmy.rtp.devcom-arl.mbx.sttr-pmo@army.mil

DEPARTMENT OF THE ARMY PROPOSAL CHECKLIST

Please review the checklist below to ensure that your proposal meets the Army STTR requirements. You must also meet the general DoD requirements specified in the BAA. **Failure to meet all the requirements may result in your proposal not being evaluated or considered for award**. Do not include this checklist with your proposal.

1. The proposal addresses a Phase I effort (up to **$204,000.00** for up to six-month duration).

2. The proposal is addressing only **ONE** Army BAA topic.

3. The technical content of the proposal includes the items identified in the DoD BAA Preface.

4. STTR Phase I Proposals have six volumes: (1) Proposal Cover Sheet, (2) Technical Volume, (3) Cost Volume, (4) Company Commercialization Report (CCR), (5) Supporting Documents, and (6) Fraud, Waste, and Abuse Training.

5. The Cost Volume has been completed and submitted for Phase I effort. The **total cost should match** the amount on the Proposal Cover Sheet.

6. If applicable, the Bio Hazard Material level has been identified in the Technical Volume.

7. If applicable, include a plan for research involving animal or human subjects, or requiring access to government resources of any kind.

8. The Phase I Proposal describes the "vision" or "end-state" of the research and the most likely strategy or path for transition of the STTR project from research to an operational capability that satisfies one or more Army operational or technical requirement in a new or existing system, larger research program, or as a stand-alone product or service.

9. If applicable, Foreign Nationals are identified in the proposal. Include country of origin, type of visa/work permit under which they are performing, and anticipated level of involvement in the project.

ARMY STTR PROGRAM COORDINATORS (PCs) and Army STTR 24.B Topic Index

Participating Organizations	PC	Email
DEVCOM-Armaments Center	Benjamin Call Peter Susberich	Benjamin.d.call.civ@army.mil Peter.a.susberich.civ@army.mil
DEVCOM-Aviation and Missile Center	Dawn Gratz Jordan Davis	Dawn.m.gratz.civ@army.mil Jordan.d.davis37.civ@army.mil
DEVCOM-ARL/Army Research Office	Michael Caccuitto	Michael.j.caccuitto.civ@army.mil
DEVCOM-C5ISR Center	Tamarisk Gillespie	Tamarisk.d.gillespie.ctr@army.mil
DEVCOM- Chemical Biological Center	Martha Weeks	Martha.g.weeks.ctr@army.mil
CoE-Environmental Research and Development Center (ERDC)	Melonise Wills	Melonise.r.wills.civ@army.mil
DEVCOM-Soldier Center	Cathy Polito	Cathryn.a.polito.civ@army.mil
DEVCOM-Ground Vehicle Systems Center	Connor Skrobot Eric Johnson	Connor.j.skrobot.civ@army.mil Eric.s.johnson212.ctr@army.mil

Version 2

Army STTR 24.B Topic Index

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A24B-T001 TITLE: Hexavalent Chrome Replacement for Small Caliber Barrels

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Materials

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 and demonstrate a high temperature, corrosion, and wear resistant hexavalent chrome replacement for use on small caliber weapon system barrels.

DESCRIPTION: Small caliber weapon system barrels operate in a high temperature, chemically corrosive, and high mechanical wear environment. This environment leads to rapid deterioration of substrate materials and ultimately, failure of the barrel to meet performance requirements. In extreme cases, the combination of extreme environments can cause catastrophic failure of the weapon system component, resulting in injury to the operator. Future weapon systems are anticipated to further push the extremes with a combination of hotter flame temperature and more chemically corrosive propellants, higher pressures, and harder projectiles. Chrome application processes result in environmentally hazardous byproducts and does not sufficiently perform under the required conditions

There is a need for the development of coatings / plating for barrel bores internal surfaces which can perform / remain adhered under extreme temperatures, and which prevent chemical and mechanical corrosion associated with small arms firing. Proposed coatings / plating shall be compatible chemically, thermally, and mechanically with a variety of materials, both traditional and novel. Proposed coating / plating materials and application processes shall be compatible with small caliber barrel bores as small as 5.56mm in diameter. Further, application processes shall take into account the requirements of the coated / plated components in the small arms system - the application processes shall not adversely affect the substrate material in ways that may affect performance, including dimensional changes or effects on material properties, such as strength or fatigue life.

PHASE I: Phase I is expected to yield the following:

- Baseline or existing coating / plating properties to be used as starting point for this application, including: Coating thickness, Coating hardness, Coefficient(s) of friction, Corrosion resistance, Color ranges, Operating temperatures and thermal stability, Adhesion to substrate, Chemical compatibility, Application limitations, including internal diameter limitations, Line of sight or Non-Line of sight, substrate compatibility, etc.
- Baseline or existing coating / plating application parameters, including: Application temperature, Application time, Other relevant application parameters,
- Baseline or existing coating / plating performance, including: Description of the system and operating environment that the existing coating is applied to,
- Performance metrics and data in that application
- Cost of the baseline or existing coating / plating
- Estimated or predicted properties of the proposed coating / plating, including: Coating thickness, Coating hardness, Coefficient(s) of friction, Corrosion resistance, Color ranges, Operating

temperatures and thermal stability, Adhesion to substrate, Chemical compatibility, Application limitations, including internal diameter limitations, substrate compatibility, etc.

- Predicted application parameters of the proposed coating / plating, including: Application temperature, Application time, Other relevant application parameters
- Results of all analyses performed to show that the proposed development process will result in coating / plating that will meet the Government's needs, including:
- Results of modeling and simulation, Results of all analyses, including chemical, thermal, and structural analyses, Ability of the coating / plating to be applied to the internal bore of the barrel, Overall predicted performance in use as a small caliber bore coating or an internal signature suppressor coating
- Estimated cost of proposed coating / plating

The Offeror is encouraged to provide any other relevant information at the conclusion of Phase I to substantiate that the proposed technology is sufficiently feasible to proceed to Phase II.

PHASE II: The primary deliverables for Phase II should include:
Development of one or more coating(s) / plating(s) formulations and associated application processes that meet the Government's requirements. This deliverable includes all necessary documentation to define the formulation as well as the application process.

A comprehensive report that documents the entirety of the effort. The report shall highlight the development process, results of all analyses performed throughout the development process, results of destructive testing (i.e. coating thickness in sectioned barrels), and contractor's test results in lab (coupon testing) as well as simulated operational environment (live fire testing of coated barrels. The report shall highlight and address any shortcomings in performance, propose potential fixes to these shortcomings, and shall address any anticipated challenges with scaling to full rate production. The report shall also provide estimates of the cost to implement the proposed coating / plating in a production setting.

Quantity of five (5) small caliber barrels with coated / plated bores (weapon system / caliber to be determined - barrels may be provided as GFM).

PHASE III DUAL USE APPLICATIONS: The following post Phase II R&D efforts will be instrumental to transition:

- Additional Science and Technology development of coatings to improve performance in extreme operating regimes
- Application of coating / plating to additional quantities of barrels that represent either challenging performance requirements or challenging application requirements.

Virtually all small caliber weapon systems, commercial and military, would benefit from improved barrel systems. There is a large commercial market for small arms, and much money is spent by individuals upgrading barrels. An Offeror would likely need to partner with an OEM barrel manufacturer and have this technology offered as part of the item itself, since it is unlikely that existing barrels would be able to be coated or plated at a reasonable cost to the consumer.

From the DoD/military side, again the technology would apply to virtually all small arms systems, but primarily to advanced next generation systems or legacy belt fed systems that generate large amounts of heat, chemical erosion, and mechanical wear from the projectile. For newly acquired systems, Program Management offices could include this technology as part of the TDP. For legacy systems, the technology could be added to TDPs as Engineering Change Proposals (ECP) and could be included in weapon system overhauls and rebuilds.

REFERENCES:
1. Xiaolong Li, Yong Zang, Lei Mu, Yong Lian, Qin Qin, 2020, Erosion analysis of machine gun barrel and lifespan prediction under typical shooting conditions, Wear, Volumes 444-445, 203177, ISSN 0043-1648, https://doi.org/10.1016/j.wear.2019.203177;
2. Sopok, Samuel. (2010). Modeling Gun Bore Heat Transfer & Degradation. 10th AIAA/ASME Joint Thermophysics and Heat Transfer Conference. 10.2514/6.2010-5063.;
3. Wear and Erosion in Large Caliber Gun Barrels, Richard G. Hasenbein, https://apps.dtic.mil/sti/pdfs/ADA440980.pdf;
4. Understanding and Predicting Gun Barrel Erosion, Ian A. Johnston, https://apps.dtic.mil/sti/pdfs/ADA440938.pdf

KEYWORDS: hexavalent chrome, barrel, advanced coating, high temperature, bore erosion, small caliber, small arms

A24B-T002 TITLE: Zernike Polynomials via Phase Recovery

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: Technology capable of completely characterizing an optic under test by implementing phase recovery and a collimated, partially coherent light source.

DESCRIPTION: Developing this capability will enable improved resolution in the Army's ubiquitous direct view optical systems. This advance will improve soldier survivability and lethality due to increased situational awareness and greater ability to detect, classify, recognize and identify (DCRI) threats.

The United States Army requires the ability to completely characterize optical systems to validate their design and performance. Commercial systems can measure the Modulation Transfer Function (MTF), effective focal length, field curvature, and distortion. These systems monitor the Fourier transform plane of the lens under test (LUT). They are currently unable to extract coma and spherical aberrations. Hopkins or Seidel coefficients that pertain to ray traces do not form an orthonormal basis; however, the Zernike polynomials are a proper basis that describes wavefront error. Frame captures contain only intensity information, and recovering the Zernike coefficients requires phase recovery. The Hubble Space Telescope was characterized by Brady (2005) and Fienup (1993) using a variation of the Gerchberg-Saxton algorithm (Wittle, 2018). Phase recovery is an inverse problem and requires constraints. Normally one uses two planes: the image plane and the Fourier transform plane. Other methods may be employed, e.g., the use of a series of frame captures about the Fourier Transform plane (Dube, 2018; Zhou, 2021; Gureyev, 2004); Mehrabkhani, 2017; Volkov, 2001). Pinhole illumination is assumed in advance. This would be near the effective focal length of the LUT. Because this is near the waist of the caustic, there is a concern as to how much (Fisher) information is available. Thus, the auxiliary planes will need to be near the region of maximum curvature for the caustic. In the far field, one can use the Fraunhofer approximate for the more general Huygen-Fresnel (H-F) propagator. Whether a Fresnel approximation is valid may depend upon the f-number of the LUT.

The acquisition of off-axis terms will require that the lens be rotated about its second nodal point. This is also true for interferometric approaches (Gates, 1955; ZYGO). The rotation of the LUT also satisfies the conditions outlined in Zhou (2021). As implemented, it is a form of tomography. Neither compressive sensing (Candes, 2011; Li, 2020) nor any other solution that requires the addition of optical elements (Fuerschbach, 2014) such as phase screens or beam splitters into the optical path are of interest for the purpose of this topic. Assume that the aberrated Airy disk is commercially examined via a microscope objective and image sensing array.

PHASE I: Develop the algorithms needed for implementing phase recovery using a series of planes about the location of the Fourier transform plane of the LUT. Demonstrate that the algorithm can converge to solutions that are consistent with those derived from interferometric methods. Determine the criteria for setting the spacing between these planes for best performance.

PHASE II: Using the results from phase I, develop the hardware and software to realize the procedure on a commercial system. Plane locations can be manually entered and the images offloaded for processing.

PHASE III DUAL USE APPLICATIONS: Make the necessary hardware and software adjustments to a commercial platform, automate the acquisition procedure, and automate the extraction of the Zernike polynomials.

REFERENCES:

1. Brady (2005), Gregory R. and James R. Fienup; "Phase retrieval as an optical metrology tool"; In Optifab 2005: Technical Digest (Vol. 10315, pp. 143-145). SPIE. Proceedings of SPIE - The International Society for Optical Engineering. 10.1117/12.605914.;
2. Candes (2011), Emmanuel J., Thomas Strohmer and Vladislav Veroninski; "PhaseLift: Exact and Stable Signal Recovery from Magnitude Measurements via Convex Programming"; arXiv:1109.4499v1 [cs.IT] 21 Sep 2011.;
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6. Gureyev (2004), T.E.; A Pogany, D.M Paganin, S.W Wilkins, "Linear algorithms for phase retrieval in the Fresnel region"; Optics Communications,Vol. 231; Issues 1–6, Pp. 53-70,; ISSN 0030-4018,; https://doi.org/10.1016/j.optcom.2003.12.020.;
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9. Volkov (2001), V., & Zhu, Y.; "Phase Retrieval from Two Defocused Images by the Transport-Ofintensity Equation Formalism with Fast Fourier Transform". Microscopy and Microanalysis, 7(S2), 430-431 Aug. 5-9 Long Beach CA; doi:10.1017/S1431927600028221;
10. Wittle (2018), Lily. Investigating the Gerchberg-Saxton Phase Retrieval Algorithm. SIAM Undergraduate Research Online. 11. 10.1137/17S016610.;
11. Zhou (2021) Guocheng, Shaohui Zhang, Yayu Zhai, Yao Hu, Qun Hao; "Single-Shot Through-Focus Image Acquisition and Phase Retrieval from Chromatic Aberration and Multi-Angle Illumination"; Frontiers in Physics, vol.9; DOI=10.3389/fphy.2021.648827; https://www.frontiersin.org/articles/10.3389/fphy.2021.648827;;
12. ZYGO "Typical Interferometer Setups"; https://www.zygo.com/-/media/project/ameteksxa/zygo/ametekzygo/downloadables/brochures/interferometers/typical-interferometer-setups.pdf]
13. Wang, B., Wang, X., & An, Q. (2020, July 7). Aberration retrieval by incorporating customized priors for estimating Zernike coefficients. Scientific Reports, 10, 11137. Retrieved from https://doi.org/10.1038/s41598-020-68012-3.

KEYWORDS: Phase Recovery, Zernike Polynomials, Fresnel Propagator, Inverse problem, Constraints, Priors.

A24B-T003 TITLE: High Reflector Microstructure for 1 Micron Continuous Wave Light and Mid to Long Wave Transmission

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Directed Energy (DE), Space Technology, Advanced Materials

OBJECTIVE: Build a microstructure designed for dielectric optically-transparent materials to act as a narrowband (1030 to 1070nm) high-reflector for cw laser light, while maintaining high transmission in the MWIR to LWIR.

DESCRIPTION: There is a need to develop highly reflective microstructures for the 1030 to 1070 nm range for continuous wave (cw) laser light to protect and allow uninterrupted operation of mid-wave to long-wave infrared sensors. Such microstructures will efficiently block the specified range of wavelengths while transmitting light in the rest of the infrared spectral region and maintaining good optical imaging quality.

The primary goal of the current STTR is to develop a microstructure, which can be etched onto a variety of dielectric optical materials whose transparency regions span the infrared (specifically ZnS, ZnSe, BaF2, Silicon, Ge, and other such optics), that will be capable of reflecting greater than 99.5% of 1030 to 1070 nm light while not reducing the transmission of the substrate by more than 10% and maintaining good optical imaging quality (structural similarity index measure (SSIM) greater than 0.9) in the infrared spectral region. A microstructure capable of handling optical powers of up to 10 MW/cm2 is preferred, with an acceptance angle of at least +/- 15 degrees over a one-inch clear aperture. Proposed microstructures should clearly include an efficient mechanism for dissipating the absorbed or reflected optical energy at the specified wavelength range. Materials should not be limited to traditional optical materials; instead exploitation of compatible material platforms suitable for operation in the infrared spectral range is encouraged. Ability of the chosen material to dissipate the required optical power and operate under standard military specification should be addressed. The proposed designs should be both polarization and vibration insensitive. Fabrication techniques needed to realize proposed filter designs should be clearly defined in the Phase I effort. Such structures should be scalable for dielectric optics with a diameter up to 5 inches.

Nano-structure resonant surfaces, a type of microstructure, consist of an array of index variations formed by holes or mesas. Typically, the array is etched into a substrate like fused silica and then conformally coated with a thin layer of higher index material like aluminum oxide or tantalum pentoxide. This gives a high low index contrast and periodic variation in a direction transverse to the beam propagation direction. In this way you can set-up a filter function in a single structured surface that performs as well as 50 to 200 thin-film layers typical of an interference filter. Interference Filters accumulate their resonance in the longitudinal direction. This is one of the major advantages of nano-structure resonant (NSR) reflection (notch transmission) filters.

Such cw microstructures are useful for commercial applications that use 1030 to 1070nm lasers for manufacturing, as well as other industrial applications where protection of the operator and the environment is required to avoid damage from high intensity laser radiation. The cw high reflector microstructure filters will provide uninterrupted, enhanced force protection and day/night situational awareness. There exist numerous military applications for this technology which can be further discussed at the CUI and higher levels.

PHASE I: Design, analysis and fabrication of a cw high reflector microstructure for dielectric optical materials capable of reflecting greater than 99.5% of 1030 to 1070 nm light, while not reducing the transmission of the unaltered substrate in the rest of the MWIR, and LWIR (3 µm to 12 µm) spectral regions by more than 10% and not degrading the optical quality of the transmitted light significantly (SSIM greater than 0.9). A microstructure capable of handling optical power densities up to 10 MW/cm2 is preferable with an acceptance angle of ± 10 degrees over a one-inch clear aperture. These filters should be both polarization and vibration insensitive. The deliverables shall include a detailed design for a high reflector microstructure on four of the substrate materials (zinc selenide, and three of the following: zinc sulfide, barium fluoride, silicon, and germanium). Include simulation results of the transmittance and reflectance spectra spanning the full spectral range (400 nm through 12 µm) along with a prototype coupon, i.e. a small-scale device 1in2 or larger with full functionality, as a proof of concept that demonstrates critical aspects of the manufacturing, and clearly demonstrates the capability to actualize the proposed reflectors.

PHASE II: Fabrication and demonstration of prototype cw high reflector microstructures with a 2 inch clear aperture (but scalable up to a 4 inch clear aperture), with an acceptance angle of ± 15 degrees, on four of the substrate materials (including ZnSe). The filter should be capable of rejecting greater than 99.5% of 1030 to 1070 nm continuous wave light, while not reducing the transmission in the rest of the 3 µm to 12 µm spectral region by more than 10% and not degrading the optical quality of the transmitted light significantly (SSIM greater than 0.9). Additionally, the reflectance should be polarization insensitive. They should also be capable of handling optical power densities up to 10 MW/cm2. Damage testing will be conducted at the U.S. Army Research Laboratory with a 200 µm to 900 µm beam spot size. The expected deliverables are at least four fully-operational prototype cw high reflector microstructures on four different materials covering the spectral range of 3 µm to 12 µm. Deliverables will be tested for cw damage threshold and within sensor systems. Also, potential commercial and military transition partners for a Phase III effort shall be identified.

PHASE III DUAL USE APPLICATIONS: Further research and development during Phase III efforts will be directed towards a final deployable design, incorporating design modifications based on results from tests conducted during Phase II, and improving engineering/form-factors, equipment hardening, and manufacturability designs to meet the U.S. Army CONOPS and end-user requirements. Manufactured cw high reflector microstructures shall be integrated into relevant systems.

Potential commercial applications include protection of thermal cameras for Private security. The possibility to incorporate these structures onto other glasses could also be explored, for the potential protection of any infrared systems.

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3. Hobbs, D.S., MacLeod, B.D., and Manni, A.D., "Pulsed laser damage resistance of nanostructured high reflectors for 355nm” Proc. SPIE 10447, 104470W (2017) LASER DAMAGE SYMPOSIUM XLIX

KEYWORDS: high power, continuous wave, microstructure, 1 micron, optics, infrared, high reflector, dielectric, high transmission, MWIR, LWIR, reflective

A24B-T004 TITLE: Metamaterials Based on Magnetic Shape Anisotropy for K-band Microwave Applications

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Materials

OBJECTIVE: Develop a metamaterial utilizing magnetic shape anisotropy of ferromagnetic nanoparticles for operation of ultracompact antenna in the K frequency band of the microwave spectrum.

DESCRIPTION: Metamaterials demonstrating resonant response to electromagnetic radiation in the microwave Ku (12 GHz to 18 GHz) and K (18 GHz to 26.5 GHz) bands are highly desirable for multiple applications, including ultracompact microwave antennae, radar detection and frequency-selective wireless heating. Availability of ferromagnetic materials with high saturation magnetization and low magnetic damping [1,2], combined with recent advances in nanolithography, enable the development of such metamaterials based on arrays of ferromagnetic nanoparticles, where the resonance frequency of the metamaterial is determined by the magnetic shape anisotropy of the nanoparticles [3]. The shape anisotropy enables fabrication of devices with a selection of operation frequencies via lithography. For example, arrays of ultracompact antennae covering a wide band of the microwave spectrum, where each antenna is tuned to its own resonance frequency via control of the fabricated nanoparticle shape, can be used for ultrafast monitoring of the electromagnetic environment. An important advantage of a magnetic metamaterial is independence of its resonance frequency on the antennae dimensions [4], which enables ultracompact antennae for communications with miniature devices. The metamaterial antenna gain can be further boosted via magneto-electric or magneto-resistive effects in nanoparticle-based heterostructures to reach record levels of sensitivity to microwave signals [5].

The goal of this proposal is development of magnetic metamaterials based on arrays of ferromagnetic nanoparticles that show resonant response to electromagnetic radiation tunable by the nanoparticle shape. The metamaterial must operate at room temperature without a bias magnetic field and must show tunability of its frequency via shape anisotropy in the 2 GHz – 26.5 GHz frequency range (covering S, C, X, Ku and K bands). The metamaterial must exhibit resonant response to the frequency of incident electromagnetic radiation with the quality factor exceeding 100. To enable commercial applications, the metamaterial must be fabricated from a polycrystalline or amorphous ferromagnetic film deposited at room temperature by a high-throughput technique such as sputtering or electrodeposition. Operation of a K-band ultra-compact microwave antenna based on the shape-anisotropy metamaterial must be demonstrated. The overall antenna dimensions must not exceed 5 millimeters.

PHASE I: Develop a magnetic metamaterial defined by arrays of ferromagnetic nanoparticles that shows resonant response to electromagnetic radiation in the microwave Ku band (12 GHz – 18 GHz) at zero magnetic field and scalability of the concept to the K frequency band.

PHASE II: Determine the optimal combination of high saturation magnetization and low magnetic damping to demonstrate resonant response of the metamaterial in the K frequency band (18 GHz to 26.5 GHz) with the resonance quality factor exceeding 100 throughout that frequency band. The metamaterial fabrication process must be compatible with standard high-throughput film deposition. Demonstrate control of the resonance frequency by shape anisotropy and fabricate metamaterial samples operating in the S, C, X and Ku microwave bands. Design, implement and test an ultra-compact (dimension below 5 mm) K-band antenna based on the shape-anisotropy metamaterial. Demonstrate the possibility of higher antenna gain using magneto-electric or magneto-resistive effects. Provide a sample of the metamaterial and the K-band antenna to the Army for further testing.

PHASE III DUAL USE APPLICATIONS: The ultracompact microwave antennae based on shape-anisotropy magnetic metamaterial can be used as receivers in miniature autonomous vehicles. An array of such ultracompact microwave antennae enables continuous monitoring of the electromagnetic spectrum over a wide microwave band, which can be used for rapid detection of threats with known electromagnetic signatures.

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KEYWORDS: magnetic metamaterial, shape anisotropy, microwave antenna, nanolithography, magnetic resonance

A24B-T005 TITLE: Aluminum Nitride-Based Monolithic Microwave Integrated Circuits

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics

OBJECTIVE: To develop aluminum nitride-based platform for monolithic microwave integrated circuits for extreme radio frequency and high-power operation.

DESCRIPTION: The next generation of devices and systems for electronic microwave applications need to offer high frequencies, high power, compactness, high-performance, and high temperature operation. Several materials platforms such as silicon carbide (SiC), gallium arsenide (GaAs), silicon (Si), and aluminum nitride (AlN) are competing for market share in this emerging high frequency applications. Among them however, AlN stands out as an exceptional material for next-generation monolithic microwave integrated circuits (MMICs), offering a multitude of advantages that are paramount for advanced electronic systems. These include its ultrawide and direct bandgap (6.2 eV), large critical electric field (15 MV/cm) and high thermal conductivity (~340 W/mK) allowing for efficient heat dissipation, critical in maintaining high power operation and reliability of high-frequency circuits. Current research and development focus is being placed on gallium nitride (GaN) and aluminum gallium nitride (AlGaN) high electron mobility transistors (HEMTs) for operations requiring both high-power and high frequency. This has led to demonstration of the state-of-the-art GaN HEMTs with output power of up to 8.84 W/mm at up to 94 GHz. However, the GaN HEMTs were fabricated on SiC substrates. AlN's compatibility with GaN and AlGaN HEMTs facilitates seamless integration, avoiding the lattice mismatch issues encountered in SiC substrates. This would enable the development of compact, high-frequency devices with superior operational capabilities. Additionally, current availability of insulating AlN of high substrate quality and large enough size ensures precise and reliable MMIC fabrication, and unwanted electrical interactions, thus, enhancing signal integrity at high frequencies. However, despite these advantages, research and development of AlN-based MMICs are still in their infancy and more effort is needed to fully harness its capabilities. The utilization of high-purity semi-insulating AlN as a substrate for MMICs requires precise knowledge of materials properties of AlN at millimeter-wave frequencies (such as electrical permittivities) to accurately predict the propagation delay and attenuation of waves along the transmission lines.

The goal of this topic is to leverage recent achievements in AlN and AlGaN and create commercializable AlN-based MMICs which outperforms current state-of-the-art GaN MMICs for higher power/frequency applications. The needed work includes fundamental research and development to establish materials properties and fabrication routes for AlN-based devices. This would require design and fabrication of resonators for microwave or RF circuits, which could be accomplished via closed-loops, circular waveguides, or transmission lines to allow for resonance at specific microwave frequencies. The developed resonators would be used to extract fundamental materials properties such as permittivity and loss tangent. Subsequently, a route towards integration of the developed resonators with typical electronic components need to be pursued, focusing on the proposer’s defined application. The anticipated product is a fully integrated microwave circuit presented as a prototype.

PHASE I: In phase I, the awardee will describe a few important Army-relevant applications for AlN-based MMICs and select the particular application they wish to address. Using this application as a testbed, AlN-based microwave/mmWave resonators should be designed and fabricated. The fabricated resonators should be used to extract the substrate’s frequency-dependent material properties up to W-Band (i.e., 1 to 75 GHz). This information should then be used to design, fabricate, and test transmission lines with return loss < 10 dB and insertion loss < 0.6 dB/mm up to 75 GHz. At the end of Phase I, the feasibility of AlN-based MMICs should be assessed. With the growing demand for high frequency and high power MMICs for military and civilian applications, mmWave MMICs based on AlN projects strong commercialization potential.

PHASE II: During Phase II, the awardee will design, fabricate, and characterize the AlN-based resonators to obtain frequency-dependent material parameters up to 170 GHz. The performer must demonstrate a process for substrate thinning to a thickness of 100 µm or smaller. In addition, through substrate vias (TSV) should be demonstrated with a diameter less than 100 µm. This will result in the design, fabrication and characterization of low-loss waveguides and waveguide transitions with demonstrations in the W- and D-bands. The peak return loss and average insertion loss should be <18 dB and <0.5 dB/mm, respectively, up to 170 GHz. Then, in order to demonstrate the feasibility of AlN-based MMICs, the awardee will integrate the waveguides with an electronic element aligned with the proposed application, such as an amplifier, mixer, oscillator, or switch. At the end of Phase II, the awardee should demonstrate that the developed systems address limitations of current systems for the chosen application. In addition, the awardee should thoroughly investigate the commercial transition potential of AlN-based MMICs. Given their potential to advance high-frequency electronics significantly, the awardee is encouraged to explore this avenue, potentially positioning themselves as a key player in industries such as telecommunications, aerospace, and defense, where advanced electronic solutions are in high demand.

PHASE III DUAL USE APPLICATIONS: During Phase III approach, the work from Phase II should be continued. Here the focus should be on the development of a truly integrated MMIC. The awardee should undertake reliability testing/qualification, produce a process design kit. Moreover, the potential to transfer the technology to military systems (e.g., radar, electronic warfare, communication), as well as civilian applications should be explored. The awardee should work with Army primes and industry partners to commercialize the technology via a trusted foundry for technology availability to the defense and military markets.

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KEYWORDS: Aluminum Nitride, MMICs, Ultra-Wide Bandgap, High Frequency, Microwave, mmWAve

A24B-T006 TITLE: Fast Charge Silicon Anode Lithium-Ion Cells for Small UAS Systems

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Renewable Energy Generation and Storage, Advanced Materials

OBJECTIVE: Fast charge silicon anode lithium-ion cells for small UAS systems.

DESCRIPTION: The ability to fast charge (less than 6 minutes) commercial graphite anode Li-ion cells to specific energies greater than110 Wh/kg is a significant challenge. The inability to fast charge to higher specific energy means that more batteries must be in the logistics chain to supply operations and that onboard/critical edge charging is not an option for many fast-paced operations. A promising technology that is currently being developed for high energy Li-ion cells (300-400 Wh/kg) is based on silicon (Si) anodes that have demonstrated fast charge capability in prototype cells. The challenges with Si anode cells are cycle life, calendar life, and safety. Many Si anode cell developers are focused on achieving the highest energy batteries and not on the ability to fast charge with long cycle or calendar life.

Cell capacity, safety, and cycle life typically suffer when Li-ion cells are charged quickly with the limitations mainly relating to the graphite anodes inability to absorb lithium ions without plating lithium metal. Si anodes alloy with lithium and demonstrate capacities 10X that of graphite at a potential and electrode thickness that make lithium plating much less likely under fast charge. Si anode cycle life is lower than commercial graphite systems due to several factors including the mechanical grinding of the Si alloy under repeated cycling that leads to loss of active material contact as well as the continuous new surface generation and subsequent passivation that occurs as the Si swells and contracts upon charge and discharge. Calendar life is poor in these systems which limits its use in EV applications, but for several specialty applications, the specific energy provides much needed capability.

Energy sharing between energy sources (vehicles, generators, solar chargers) and Soldiers already occurs when BB2590 batteries are charged in the field. The charging process is slow and often it is easier to swap batteries if available. Fast charge batteries are part of the DEVCOM Army Research Laboratory VICTOR (VERSATILE TACTICAL POWER AND PROPULSION) Essential Research Program and in tandem with wireless recharge and silent power generation, will eliminate battery swaps, reduce the cognitive and physical load on Soldiers, and reduce the logistical tail in batteries. One example is the use of fast charge batteries in small unmanned air systems (sUAS) charged from mobile ground stations that enable autonomous recharge, freeing the Soldier from carrying and changing batteries, and reducing their exposure on the battlefield.

This topic seeks the development of Si based fast charge cells with demonstrated specific energy greater than 200 Wh/kg in 6 minutes of charge in order to enable new concepts in energy sharing, increased pace of operations, and compact energy sources for high power devices. This topic looks to have Si anode materials brought further into development and to demonstrate the improvements in full Li-ion cells for use in VICTOR ERP programs.

PHASE I: In the phase I effort, demonstrate single/few layer Si anode full cells that when fast charged at 10C (6 minute) rates, cycle for >1000 continuous cycles at 3C discharge to > 80% capacity. These cells should support the development of multi-Ah cells with a specific energy > 200 Wh/kg. Deliverables would be 10 full cells of >100 mAh capacity capable of 10C charge / 3C discharge and >1000 cycles to > 80% capacity.

PHASE II: Phase II would involve producing and characterizing cells in sufficient quantities to fully characterize them for rate, temperature performance, and continuous cycling stability. Deliverables include 20 full cells at a rated capacity of > 2Ah capable of 10C/3C charge-discharge cycling at an energy density of >200 Wh/kg at the 10C charge rate.

PHASE III DUAL USE APPLICATIONS: The applications where this technology could be used include storage for high energy storage modules (HESM), jammer applications, 6T battery applications, and for fast charge batteries in UAS systems. Commercial applications include batteries for hybrid electric vehicles and eVTOL. Likely sources of funding if the phase III program is successful include PEO Soldier, PM UAS, and C5ISR.

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KEYWORDS: Fast charge, Lithium-ion, Silicon anode, High power

A24B-T007 TITLE: Multicomponent Reduced Order Modeling of Hypersonic Boundary Layers

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: To develop multi-physics component-based reduced order models (ROMs) and associated interfaces to accelerate high-fidelity design tools for predicting detailed time-accurate hypersonic vehicle flow-fields.

DESCRIPTION: The Army is interested in designing next-generation hypersonic flight vehicles with enhanced system speed, reach, and lethality addressing Army's and DoD's Priorities in Long Range Precision Fires and Hypersonics. Revolutionary systems must meet new tactical requirements for performance, reach, and lethality. Computational fluid dynamics (CFD) has played a central role in the design and development of hypersonic vehicles, in part due to prohibitive costs associated with testing facilities. However, existing CFD approaches have prohibitive computational costs when attempting to predict high Reynolds number hypersonic aerothermodynamics and its interactions with fully resolved physical processes. Hypersonic modeling under realistic flight conditions is complicated by the nonlinearity and multiphysics nature present that acts across a wide range of scales [1]. Variations in atmospheric conditions, chemical kinetics, vibrational excitation, ablation products, and gas-surface interactions further complicate high enthalpy flow and plasma [2]. Recent detailed direct molecular simulations have also demonstrated macroscopic impacts of complex transport phenomena often omitted in coarse grained models such as Large Eddy Simulation (LES) and Reynolds Averaged Navier Stokes [3,4]. The computational expense associated with solving complex coupled fluid, thermal, kinetic, and structural problems currently significantly limit the rate at which design space can be accurately explored. Recent success accelerating modeling of complex flows of similar computational complexity through component-based ROMs[5] suggests potential for model acceleration strategies that exploit coupling of local mesoscale ROM domains. Newly developed localized ROM domain partitioning, nonlinear compression, and adaptivity suggest potential to attain greater efficiency and scalability than start-of-the-art models through the mitigation of high Kolmogorov n-width complexity associated with device scale transient turbulent flows. To shorten design cycles, revolutionary capabilities for accelerating high fidelity external and internal aerothermodynamics such as these must also be integrated with associated multi-physics couplings. The Army is therefore soliciting scalable adaptive model order reduction technologies capable of recovering high-fidelity predictive power for the flight environment of a hypersonic vehicle, along with associated gas-flow chemistry, detailed transport, shock induced heating, and their associated material-responses. The goal will be to achieve at least an order of magnitude reduction of computational cost versus existing wall-resolved LES (WR-LES) techniques while recovering full Direct Numerical Simulation (DNS) accuracy levels on transitional flows where wall-modeled (WM-LES) results diverge from WR-LES and DNS solutions. While either non-invasive data-driven model order reduction or fully invasive ROM technologies will be considered, priority will be given to approaches that develop modular compressed bidirectional data interfaces that enable tight coupling among diverse physics tools with improved scalability. The new tools should be able to handle realistic glide body, missile geometries, and scramjet propulsion systems for sustained powered flight in the Mach 6 to 20 range. Models that reduce sensitivity to near-wall mesh quality are particularly encouraged. Tools must have the ability to be deployed in traditional/emerging high performance computing architectures (CPU GPU) efficiently and demonstrate efficient weak scaling at least competitive with LES models. Compressed interfaces for in-situ visualization and data extraction techniques enabling seamless navigation of the sea of data encountered in real-time analysis is also encouraged.

PHASE I: Develop component-based reduced order model (ROM) technologies that, once trained, demonstrate accurate 3D high-fidelity prediction of transient hypersonic boundary layer flows with transition for novel flow conditions within training set bounds. Attain order of magnitude reduction in memory footprint compared to existing state-of-art WR-LES of commensurate accuracy without explicitly defined wall models. Ability to recover DNS level solution accuracy in geometries incompatible with existing wall models should also be demonstrated with order of magnitude speedup relative to state of the art fully resolved high-order DNS solutions. Performance scaling for high fidelity reacting turbulence commensurate with DNS solutions with finite rate chemical kinetics and detailed transport should also be demonstrated. The company should identify strengths/weaknesses associated with alternative solutions, methods, and new concepts. Demonstrate theoretical credibility of proposed computational methods. Computational vetting and demonstration of concepts to be conducted using canonical blunt-nose single or double cone hypersonic shapes and simple flameholder geometries at minimal Reynolds number required to demonstrate transitional flow behaviors is suitable in this phase. Solutions capable of maintaining order of magnitude speedups with ROM training or adaptation time included without loss of predictive accuracy across parametrically varying geometric configurations are highly encouraged.

PHASE II: During Phase-II, the framework developed in Phase-I will be extended and validated to support hypersonic design of potential applications in air-breathing missiles, boost-glide missiles, and high-maneuver interceptors. Tools should demonstrate ability to model complex aerothermochemistry, transport, thermoacoustics, shock induced heating, and structural material responses with statistical properties shown to converge towards DNS and canonical experimental data with computational cost at least one order of magnitude below WR-LES models for equivalent conditions. Fluid-structure component-based ROM coupling that enables conjugate heat transfer and fluid structure interaction calculations that accurately model sharp features resulting from shock-heating are also encouraged. The tools should inherit the ability to capture in detail non-equilibrium processes including boundary layer transition to turbulence, onset of material ablation, finite-rate non-equilibrium chemistry, and gas-surface interactions responsible for surface deformation from baseline full-order DNS models. Tight-coupling of time-accurate predictions through compressed component-based ROM interfaces for fluid structure interactions for parametric variations of both flow boundary conditions and design properties for external hypersonic vehicle flows should be demonstrated. Complete model, multi-physics ROM interface application programming interfaces (APIs), and executable code for deployment on state-of-the-art high performance computing systems with demonstrable performance on existing or emerging computing architectures is expected.

Teams must demonstrate model validation by comparison with experiments, reference DNS databases in the open literature, or data from the Army or DoD laboratories. Capturing turbulent transition at dramatically reduced computational complexity for arbitrary geometries and flow conditions is emphasized. The complete software package shall be available to ARL during all phases of the project to conduct independent assessment and vetting of the developed tools. Development efforts will be coordinated with the government and potential prime-contractor partners to ensure product relevance and compatibility with missile defense projects and government modeling and simulation systems. While compatibility with specific production codes is not required, selection will favor projects with viable transition strategies for either enhancing or supplanting production codes in existing high-cost

Multiphysics analysis pipelines. The developed complete computational tool sets along with user guide(s) at the end of Phase-II shall be delivered to ARL for government use on HPC platforms to conduct mission projects.

PHASE III DUAL USE APPLICATIONS: This work will enable collaboration with high-fidelity simulation model developer(s) and/or user(s) on integration of product(s) into accelerated missile defense application pipelines. Long-term optimization of toolsets and APIs to accommodate new advances in the technology of tracking and prediction of glide body or cruise missile flight will continue. Technology will transition to an appropriate government or defense contractor for integration and testing. Integration and validation into design cycles for a real-world missile defense application will continue.

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KEYWORDS: Reduced order modeling, hypersonics, aerothermochemistry, computational fluid dynamics

A24B-T008 TITLE: Modeling Tools for Army Vehicle (tanks and rotorcraft) Mobility Applications

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

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: To incorporate new mathematical constructs and high-fidelity design tools to predict Fluid-Structure interactions of Army vehicle (tanks and rotorcraft)

DESCRIPTION: The United States Army is actively seeking to advance its capabilities in aerodynamic analysis and design for a wide range of vehicles spanning from rotary-wing aircraft to medium/long-range hypersonic projectiles. A critical need to understand and optimize flight characteristics across various mobility applications is behind this initiative. The United States Army has a need to develop high-fidelity, computationally efficient solvers for the aerodynamic analysis and design of vehicles ranging from rotary-wing aircrafts to medium/long-range hypersonic projectiles. The Army has unique gaps in understanding the flight characteristics (e.g., mobility applications, including gas-turbine engine flow and heat transfer analysis for vehicles that include these propulsion systems) and Extreme-event mitigation including air-blast FSI modeling and simulation for Army vehicles and structures. Isogeometric Analysis (IGA) has brought superior accuracy to spatial and temporal discretization in fluid and structural mechanics simulations. Complex-geometry NURBS mesh (Non-Uniform Rational B-Spline Surfaces) generation tools developed in recent years are making IGA simulations more applicable to real-world problems in fluids, structures, and fluid–structure interaction (FSI) and thus more practical and widespread. Bringing even higher fidelity and higher efficiency to IGA FSI simulations will require mid-processing tools. The mid-processing tools should include those listed below. i) More effective unstructured IGA discretization and mesh refinement tools, such as T-splines, subdivision, and locally refined B-splines. Correct prediction of hypersonic boundary layer transition locations, turbulent heat fluxes and vortical structures of high-speed wakes are of paramount importance in enabling the prediction of a next generation hypersonic vehicle’s performance.

In conclusion, enhancing the fidelity and efficiency of IGA FSI simulations represents a critical competency that provides the United States Army with advanced aerodynamic analysis and design capabilities.

PHASE I: The Phase 1 effort shall carefully assess the i) More effective unstructured IGA discretization and mesh refinement tools, such as T-splines, subdivision, and locally refined B-splines.
ii) Advanced IGA mesh moving tools, such as the method based on fiber-reinforced hyper elasticity, that significantly increase the scope and accuracy of the IGA FSI computations with body-fitted methods.
iii) Tools that will make it simpler in fluid mechanics and FSI simulations carried out with the Variational Multiscale (VMS) method to use more sophisticated and better-performing stabilization parameters, such as those targeting IGA discretization. These parameters play a key role in the stability and accuracy of VMS computations.
iv) Visualization tools that will give the users a better understanding of the performance of the IGA computational methods they are using and help them steer the simulations to even higher fidelity.

One of the Phase 1 outcomes will be outline of Phase 2 schedule for implementation of Advanced IGA mesh moving tools. Another outcome will be a report summarizing the assessments, a plan to move forward, an estimate of the increased fidelity possible through i-iv, or a recommendation for a prioritization of which tools would be most likely to significantly enhance design tools.

PHASE II: In Phase II the mid-processing tools itemized below will be developed.

i) Advanced IGA mesh moving tools, such as the method based on fiber-reinforced hyper elasticity, that significantly increase the scope and accuracy of the IGA FSI computations with body-fitted methods.
ii) Tools that will make it simpler in FSI simulations carried out with the Variational Multiscale (VMS) method to use more sophisticated and better-performing stabilization parameters, such as those targeting IGA discretization. These parameters play a key role in the stability and accuracy of the VMS computations.
iii) Visualization tools that will give the users a better understanding of the performance of the IGA computational methods they are using and help them steer the simulations to even higher fidelity.

PHASE III DUAL USE APPLICATIONS: Collaborate with model, software developers, and users on integration of products into a Long-Range Precision Fires application. Optimize toolset to accommodate new advances in the technology delivering high-speed weapons in anti-access/area-denial environments. Transition the technology to an appropriate government agency or prime defense contractor for integration and testing. Integrate and validate the functional aerothermodynamic tools into a real-world development or acquisition program.

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KEYWORDS: Fluid-Structure interactions, hyperelasticity, modeling, design, tools, air vehicles

A24B-T009 TITLE: High Throughput, High Temperature Mechanical Test Platform

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Hypersonics

OBJECTIVE: Design, develop, and demonstrate a high-throughput mechanical test platform capable of replicating extreme thermal-mechanical-chemical environments.

DESCRIPTION: The DoD requires robust, high temperature materials for a variety of extreme thermomechanical applications, including hypersonics, advanced propulsion, and next generation materials processing. These structures may experience transient thermomechanical loads while also in the presence of harsh chemical environments that may accelerate material degradation. However, most current mechanical test practices are unable to replicate relevant environments to inform material behaviors under extreme conditions. For example, currently there are two ASTM standards available for determining the flexure strength (ASTM C1211) and uniaxial tensile strength (ASTM C1366) of ceramics at elevated temperatures. In general, “elevated temperature” may be considered as temperatures up to 1600 °C, well below the temperatures that ceramics may experience under extreme conditions, e.g. in hypersonic and advanced propulsion applications. Neither of these tests are designed for high throughput and the test fixtures may not have the thermomechanical properties to survive more extreme conditions.

Thus, new methodologies for quickly testing structural materials under relevant environments are required to accelerate materials development for extreme operating conditions. A variety of sub-scale, high-throughput experimental techniques have emerged as potential routes for quickly screening candidate materials, although more research is needed to assess whether these approaches are representative of full-scale testing.

If successful, this effort would enable a novel characterization tool that would be capable of simulating the extreme operating environment to rapidly assess next generation materials expected to experience harsh thermal, mechanical, and chemical loads.

PHASE I: Identify a methodology and initiate fixture fabrication along with associated hardware/software to perform high-throughput, high temperature mechanical testing of materials. The specific methodology is not prescribed but must be capable of performing mechanical testing in relevant thermal environments. Specific capabilities that are desired include: the ability to rapidly vary and control the temperature of the sample while simultaneously performing mechanical characterization. The approach should incorporate automation where possible to enable rapid assessment (e.g., in sample preparation, sample loading, testing, and/or data analysis). To maximize testing and data throughput, the concept must demonstrate at least a 10-fold improvement in the rate of experimentation over current manual high temperature mechanical testing techniques. The method should be tailored for research and development of next-generation structural materials for extreme environments, e.g. ultrahigh temperature ceramics, carbon-carbon composites, and/or refractory metals. The concept must also outline an approach for assessing the accuracy of the method with respect to current testing standards (e.g. ASTM C1211 and C1366). Develop a Phase II plan.

PHASE II: Design and develop a high-throughput, high temperature mechanical test platform with the ability to rapidly vary and control environmental conditions as prescribed by the user. Validate the thermomechanical characterization method with conventional testing approaches. In addition, performer should outline a plan for integrating atmospheric control and/or surface characterization methods to determine sample degradation due to the thermal-mechanical-chemical environment, e.g. through modular fixtures that enable imaging and/or emission spectroscopy techniques. It is recommended that the performer work with bulk material vendors/Original Equipment Manufacturers (OEMs) and/or high temperature material testing agencies to facilitate transition for Phase III. Successful completion of

Phase II shall include a demonstration to DEVCOM Army Research Laboratory scientists and engineers engaged in high temperature testing of materials for extreme thermomechanical environments.

PHASE III DUAL USE APPLICATIONS: The completion of this effort would provide an automated tool that receives, prepares, assesses, and analyzes the high temperature performance of materials in extreme thermal-mechanical-chemical environments in a way that accurately reflects the full-scale behaviors of the structures. Phase III will transition high throughput, high temperature materials testing techniques to commercial suppliers through bulk material vendors, OEMs, or other partnering agreement(s). Commercialization of this technology may be through the development of kits or modules for retrofitting existing high temperature testing apparatus, or through the development of full turn-key systems. Spatially and temporally measuring surface chemistry in these environments is of high interest given the importance for understanding materials degradation as well as multi-physics behaviors, e.g. gas-materials interactions during high speed flows. Surface characterization methods may include imaging approaches, emission spectroscopy techniques, etc. If successful, this technology would provide DoD scientists and engineers a platform for rapidly assessing next generation high temperature structural materials.

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KEYWORDS: High temperature mechanical test, high temperature material, subscale testing, data-driven design, hypersonics, automation, machine learning, autonomous experimentation, high-throughput experimentation

A24B-T010 TITLE: Leveraging Advanced Computation to better employ Additive Manufacturing

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Computing and Software, Advanced Materials, Human-Machine Interfaces

OBJECTIVE: This topic seeks to advance the science of Additive Manufacturing by developing advanced in-process monitoring and parameter optimization to the 3D printing capability of local users throughout the Army.

DESCRIPTION: The Army could greatly enhance its utilization of Additive Manufacturing (AM) by better leveraging advanced computational tools and instrumentation. A more robust implementation of AM could make invaluable contributions to fielded capabilities and Soldier Lethality, as well as future systems such as Next Generation Combat Vehicle (NGCV), Future Vertical Lift (FVL), and Long Range Precision Fires (LRPF). One of the greatest handicaps faced by AM thus far has not been the printer hardware itself, but rather the ability to trust that prints have been optimally executed [5]. Subsequently, the quality of printed parts and their respective material properties is typically interrogated by destructive testing and/or the contemporaneous printing of test coupons. This post-hoc analysis is an inefficient and impractical exercise for many printer operators, especially those in remote locations. Monitoring prints in real-time, however, could alleviate the need for this after-the-fact verification and constitute a significant advancement in the Science of Additive Manufacturing. Using sensors and printer outputs to collect data, and then statistically correlating that data with resultant material properties, can yield instantaneous confirmation that the print is of baseline quality. Such a method could be significantly enhanced with advanced computational methods such as artificial intelligence and machine learning. Furthermore, the correlations between input and output can be employed not only to verify the printer output, but also to enhance the printer inputs [4]. A feedback loop using these same computational tools can be leveraged to optimize the parameters and settings of the printer to factor in material selection, part requirements, and environmental conditions. This approach could even identify and control non-intuitive contributing factors to print quality. Thus, it would be desirable for the Army to develop and field a printer kit featuring both the real-time monitoring and verification of the printing process, in addition to the fine-tuning of setup parameters. The desire for these AM-augmenting functions is not here newly articulated, having rather been under investigation for some time by various institutions. However, such investigations have typically been in a sanitary, high-resource environment using particular printer platforms [1], [2], [3]. The novelty of the proposed kit, then, is in the implementation of these features in a way that is accessible to non-experts and modular for interface with a variety of printer systems.

The proliferation of both AM hardware and widely-accessible advanced computational tools make the time ripe to develop this next advancement in the Science of Additive Manufacturing. Thus, this topic seeks to develop a modular kit, consisting of sensor, software, and computational tools, to augment the AM process. This product would afford users the ability to verify the quality of each printed part, but also ensure that the material properties of the part are optimized. A higher-quality and higher-confidence AM capability would immensely assist forward assets and Soldier Lethality, as well as affording FVL, NGCV, and LRPF far greater design space. A successful execution and implementation of this topic would thus assist both the direct users and operators of AM as well as the Army in general.

PHASE I: Identify the COTS hardware, software, and computational products relevant to this application, and begin combining them into a benchtop prototype. Initially orient the prototype toward optimizing a polymer FDM system. All prototypes must cohere with Army IT security protocols. This prototype should be demonstrated to generate recommended parameters for print an Army-relevant polymer, as well as pass/fail determination in real-time. The prototype will be evaluated by comparing test parts/coupons printed using optimized parameters against those printed by stock/automatic machine parameters.

Additionally, a methodology for modularizing the prototype (necessary for commercial viability) should be outlined.

PHASE II: Transition the benchtop prototype from Phase 1 into a modular kit capable of interfacing with different 3D printers and different materials. Develop a robust user-interface that makes the data accessible to AM technicians and machine operators. Begin testing the kit on different FDM systems and high temperature materials. Demonstrate the prototype's expanded modular capability by successfully using it on three different machines and 3 different materials. Outline a way in which this prototype could be modified/replicated to function with Laser Powder Bed Fusion process.

PHASE III DUAL USE APPLICATIONS: This technology has tremendous use-case applications within not only the Army, or DoD as a whole. It could revolutionize many aspects of AM in general. Potential transition points and commercial markets include fabrication/manufacturing entities, biomedical institutions, research institutions, and auto manufacturers. Such an "AM enhancement kit" could be sold as a standalone product, or marketed to 3D Printer manufacturers as an upgrade for their operating protocols.

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KEYWORDS: Additive Manufacturing, optimization, 3D printing, in-situ monitoring, material properties

A24B-T011 TITLE: Efficient Red Micro-LEDs with Pixel Size < 5 Microns for Next-Generation Displays and Visible Light Communication Systems

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): FutureG, Integrated Sensing and Cyber, Microelectronics, Integrated Network Systems-of-Systems, Advanced Materials, Human-Machine Interfaces

OBJECTIVE: Develop and demonstrate new micro-LED architectures which will lead to red micro-LEDs with high external quantum efficiency (>2%) when the pixel size is less than 5 microns.

DESCRIPTION: Due to their fast response, lightweight, low power consumption, and high efficiency, micro-LEDs have received considerable attention in the development of next-generation displays and visible light communication systems for strategic and tactical battlefield applications for dismounted soldiers, as well as command and control systems. Virtual Reality (VR) and Augmented Reality (AR) systems must have a high number of PPI (at least 4,000) since they emphasize the importance of small areas and high resolutions for battlefield visualization. In order to achieve the required miniaturization and high-resolution design, each micro-LED must be less than 5 microns in size.

In spite of the reduction in LED chip size to below 10 microns, GaN-based blue and green micro-LEDs retain high performance in terms of external quantum efficiency (EQE). Most red micro- LEDs, however, suffer from significant size-dependent efficiency droop as a result of serious surface recombination at the edges of the device. Existing red micro-LEDs shows EQE as low as 0.1% when their size is less than 5 microns which represents a significant challenge for next-generation high-resolution AR/VR systems.

Many approaches, such as those based on InGaN-quantum wells, quantum dots enhanced structures, etc. have been proposed in the literature to address this problem with some success. However, many of these approaches are for chips with larger dimensions than what is required in this solicitation. In spite of this, they indicate that there are potential paths towards realizing high efficient red micro-LEDs. As part of addressing this technology gap, innovations in material development and novel fabrication technologies as well as significant improvements in existing materials and processes will be necessary to minimize, if not eliminate, sidewall damage and degradation of electrical injection. Several strain engineering methodologies have also been reported in the literature, especially those relating to the fabrication of multiple quantum well structures. In order to achieve EQE greater than 2% for red micro-LEDs with a size between 2 and 5 microns, the Army is seeking solutions. A new LED architecture should be compatible with RGB full color integration and be capable of accommodating large arrays. It should be noted that we are not looking for traditional technical approaches such as sidewall passivation using ALD or micro-LED pyramids.

PHASE I: Develop a proof-of-concept solution for red micro-LEDs with pixel sizes of 2-5 microns and EQEs exceeding 2%. A detailed micro-LED architecture design and theoretical/numerical estimations of the EQE based on the pixel size must be included in the solution. Ensure that all aspects of device fabrication are considered, including a preliminary assessment of long-term environmental stability and justify the approach's feasibility and practicality. Phase I is designed to assess the technical merit, feasibility, and commercial potential of a proposed effort, and to evaluate the performance prior to providing further support in Phase II. The deliverables should include a comprehensive final report, a presentation of the concept design, models, modeling data and results, model validation data, an optional demonstration of the proof of technology, and plans for the continuation of Phase II work.

PHASE II: Using the results of Phase I, develop and demonstrate a prototype red micro-LED device that meets all the requirements stated above. The prototypes should be fabricated by using standard cleanroom processes and be capable of integrating with the existing standard LED drivers for displays. In addition, they should demonstrate the modularity of the system and prove the feasibility of large arrays during operational demonstrations. Conduct accelerated aging tests to determine the lifetime reliability and performance characteristics of the devices in both storage and operation. Deliverables must also include a detailed final report comprising a comprehensive assemblage of design documents, fabrication methods, experimental protocols, and prototype testing data and results. In addition, a full-scale prototype system with associated documentation must also be delivered to the government point of contact for independent testing and evaluation at a government laboratory.

PHASE III DUAL USE APPLICATIONS: Based on the prototypes developed in Phase II, continuing development must lead to productization of miniaturized red micro-LEDs for optical systems. Conduct testing on variety of military platforms and develop a process for a large-scale production to support potential transition partners including Army, and other DoD agencies. Despite the fact that this technology is aimed at military and strategic applications, many other optical circuit applications, including in telecom industry hardware, can also be benefited by miniaturized red micro-LEDs. The sources that can operate over a very wide range of environmental conditions are likely to bring value to many existing commercial applications. Also, technology meeting the needs of this topic could be leveraged to bring AR/VR systems toward a price point that could make them more attractive to the commercial markets.

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KEYWORDS: Micro-LEDs, Full-color display, Display devices, RGB displays, Light emitting diodes, Optoelectronic devices, Virtual reality, Augmented reality, External quantum efficiency

A24B-T012 TITLE: Engineered Bolometer Leg Materials Towards Physics-Limited Thermal Infrared Imaging Arrays

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics, Advanced Materials

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: Demonstrate an engineered material system able to be deposited and patterned with semiconductor foundry techniques with very low thermal conductivity and reasonable electrical conductivity for use as a bolometer leg.

DESCRIPTION: Bolometer technology is used in nearly all uncooled longwave imaging sensors worldwide; these sensors are widely used for both commercial and military applications on ground, personnel-carried, and air platforms. This technology supports targeting, autonomy, situational awareness, security, and many other application spaces with its inclusion into numerous Army Programs of Record (PoR) and are increasingly used as inputs to AI/ML-powered algorithms. This is because bolometer-based sensors are uniquely positioned to provide low-cost imaging in the longwave infrared (thermal) band.

Domestic U.S. industry has historically held strong advantages in both performance and number of sensor units manufactured. However, high levels of investment by foreign companies and countries has eroded this advantage. This topic seeks to extend the advantage of U.S. industry.
A bolometer-based imaging sensor is comprised of a focal plane where each pixel is a bolometer structure, a read-out integrated circuit, supporting electronics, optics, and a mechanical housing. The basic bolometer structure itself, a microelectromechanical structure (MEMS), is comprised of a transducing body and two legs. The legs serve to mechanically support the body and thermally isolate it while passing an electric current to read out the transducing body's signal.
The leg, and the materials that comprise it, are key to a highly sensitive and manufacturable (high yielding) pixel. Higher thermal isolation results in a more sensitive pixel. However, the typical way to increase thermal isolation is to make the leg longer and thinner, often wrapping around the pixel many times. This, in turn, decreases the pixel manufacturability and sensor robustness in operational use. This is especially important as bolometer pixels get smaller in support of higher resolution devices.

Therefore, this topic seeks a new material or engineered material system which is inherently more thermally isolating while maintaining electrical conductivity and mechanical robustness. This would enable a shorter, wider leg and push bolometers closer to their physical performance limit and away from the practical structural limits imposed today. This necessarily requires a material system which breaks the usual Wiedemann–Franz relationship between electrical and thermal conductivity.

To be applicable to high-rate bolometer fabrication, the material must be capable of being deposited and lithographically patterned by standard CMOS foundry equipment used in bolometer fabrication and be compatible with other portions of the fabrication and packaging processes. A low-noise ohmic contact must be formed with the substrate and bolometer body material (commonly vanadium oxide, but

sometimes α-silicon, titanium oxide, or other materials). Overall total leg thermal mass must be low to avoid degrading sensor performance.
Note that proposals will not be considered for material systems for other bolometer components (e.g., the body/transducing material), alternate sensing technologies, other components of the camera module, or anything else that is not a bolometer leg capable of mechanical support, thermal isolation, and electrical conductivity.

PHASE I: Describe one or more material systems and propose a method of fabricating the material compatible with the constraints of a semiconductor fabrication facility. Through a combination of modeling, theory, and/or experimental evidence, demonstrate that the system meets all requirements to act as a bolometer leg and is superior to materials used in current production devices. The material system will be evaluated based on it having low thermal conductivity (< 250 pW/K, ideally approaching 0), low overall thermal mass (<0.3 pJ/K), moderate electrical conductivity (ideally resistance < 250 kΩ, but up to 2 MΩ for certain readouts), ability to form low-noise ohmic contacts, low deposition thermal budget (<200°C), and overall thermal and mechanical robustness (withstand 300°C, mechanical shock and vibration). This shall be delivered in a final technical volume.

PHASE II: Further develop, fabricate, and characterize the material system. Show that the material system is capable of meeting the requirements of bolometer legs. No particular physical form is required for this demonstration, but it is desired that the final material system demonstration be as high fidelity as possible in replicating its end use as a bolometer leg (though a complete bolometer is not necessary). Formulate a fabrication process flow fully compatible with bolometer fabrication flows used by U.S. industry to promote transition of the material system. Collaboration with industry is desired to show buy-in of the material system and compatibility with production flows. Demonstrate or otherwise show that this fabrication method is low-cost, high yield, and high uniformity.

PHASE III DUAL USE APPLICATIONS: Work with a U.S.-based bolometer fabricator to transition the material system to a high-rate production environment. Support the bolometer fabricator in developing an imaging demonstration prototype LWIR bolometer sensor system, perhaps based on an existing camera/sensor product, to prove the viability and benefits of the material system for increasing performance and/or manufacturing yield. Such a material system is useful to all domestic bolometer manufacturers and could be used to improve any existing or future bolometer product (domestic or commercial use) as a 100% drop-in replacement. The enhanced sensors could then be qualified for use in any COTS or Program of Record acquisition program for operational use. Since sensors utilizing this material system would be a 100% drop-in replacement, it could be used in existing or future programs utilizing uncooled thermal technology.

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KEYWORDS: Bolometer, microbolometer, longwave, LWIR, sensor, thermal, conductivity, MEMS

A24B-T013 TITLE: Underlay Communications with Wide SINR Range

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Integrated Network Systems-of-Systems

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 utilize novel signal processing algorithms and architectures such as Canonical Correlation Analysis (CCA) to achieve high levels of interference suppression for tactical communications to support underlay wireless communications for military networks. The technology will enable a tactical communications system operating at tactically relevant bandwidths the ability to receive signals in the presence of significant co-channel primary user interference. While reduction in data capacity is expected, this reduction in data capacity will be lower compared to spread-spectrum networks.

DESCRIPTION: The Army communications networks need to operate in a congested and contested electromagnetic spectrum (EMS) environment. The tactical radio receiver in such environments may face significant co-channel interference (significantly higher than the desired received signal level). The interference may result from other EMS users, such as radio stations or radars, or other interferers such as Electronic Warfare (EW) systems. One traditional approach to sustain resilient communications in such environments is spread-spectrum communications or high-coded communications that takes advantage of the capacity vs. Low Probability of Detection (LPD) and Anti Jam (AJ) performance trades space. This approach requires significant channel bandwidth and treats the interference as noise which cannot be excised from the receiver. However, recognizing that interference is not thermal noise, this topic is looking for novel based signal processing solutions that would enable operation of communications links in the presence of considerable co-channel interference.

In cognitive radio literature, the ability to operate a link in the presence of a primary user at sufficiently low power to avoid interference with the primary user is called underlay communications. In the military context, underlay communications have many benefits, including improved spectrum efficiency, improved covertness and improved resistance to interference. The key innovation needed is the ability to operate an underlay network at a capacity that is significantly higher than would be expected if the interference was treated as noise. The technology solution should support tactically relevant bandwidths and should support single or multiple antennas radio systems. Also, it is important that the performance of the link not suffer any sharp degradation if the primary signal varies in power or behaves intermittently. The underlay system cannot assume any prior knowledge of the primary signal.

PHASE I: (Feasibility Study) The feasibility study should outline the theory of operation, describe relevant signal processing algorithms, any limiting factors and simulation results. The study should also address how the proposed physical layer may be integrated with higher-layer protocols (e.g., layer 3, etc.).

While using the algorithm, the BER shall not increase more than 6X while in the presence of interference.

PHASE II: (Prototype Delivery) Phase II should deliver a functioning underlay link physical layer prototype implemented on a widely used software defined radio (SDR) platform. The prototype should be physically provided to perform independent lab-based assessment of link performance using a set of primary signals selected. During Phase II, it is not required for the demodulation and decoding to occur in real time. For proof of concept, post-processing of the received digital signal samples is a viable approach.

An important element in Phase II is the interaction between testing and iterative software refinement by the performer. Therefore, the first iteration of the prototype should be available at least three months before the conclusion of Phase II.

While using the algorithm, the BER shall not increase more than 6X while in the presence of interference.

PHASE III DUAL USE APPLICATIONS: Phase III should deliver a real-time implementation of the algorithm using hardware acceleration if necessary. While using the algorithm, the BER shall not increase more than 6X while in the presence of interference.

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KEYWORDS: Underlay networks, spectrum efficiency, congested spectrum, contested spectrum, Symbol Error Rate (SER), Bit Error Rate (BER), Signal to Noise (SNR).

A24B-T014 TITLE: Phase Change Materials for Enhanced Warfighter Survivability

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Materials

OBJECTIVE: The Army seeks innovative solutions utilizing phase change materials tailored for thermal regulation within a Closed-Circuit Self-Contained Breathing Apparatus to reduce thermal burden, enhance operational longevity, and improve warfighter efficiency.

DESCRIPTION: This STTR topic addresses the need for an advanced material solution capable of thermally regulating the microclimate of a Closed-Circuit Self-Contained Breathing Apparatus (CC-SCBA) by acting as a heat exchanger within the system. The envisioned technology would utilize phase change materials (PCMs) that are lightweight, reusable, and regenerative, with a transition temperature tailored to the unique operational demands of tactical respiratory protection devices.

Current CC-SCBA systems place a significant thermal load on the operator, leading to increased fatigue and reduced mission duration and effectiveness. Additionally, the inherent heat generation compromises the CO2 scrubbing efficiency, curtailing system endurance. The integration of an optimized PCM matrix could surmount these limitations by regulating the temperature of inspired air, thereby enhancing warfighter lethality and survivability.

The material must demonstrate efficacy in a composite or blend format, ensuring compatibility with existing CC-SCBA configurations and surpassing the performance of conventional ice-based systems. The developed technology should demonstrate structural stability and efficient thermal exchange within the constrained form factor of CC-SCBA units. Overall, success is defined by a phase change material that extends the operating lifetime of a CC-SCBA in terms of the thermal limitations set forth by the current NIOSH standard for CC-SCBAs (42 CFR 84.103). The ideal solution is a phase change material that can maintain an inspired air temperature below 35 °C under operational flow conditions for a duration of 4 or more hours.

The development process will include the optimization of encapsulation methods to prevent leakage and enhance material integration within the CC-SCBA framework. Additionally, these materials should exhibit long-term chemical stability and resistance to thermal degradation over repeated use cycles, ensuring reliability and safety in field operations. It should also be noted that the PCM will be required to operate in nearly 100% humidity in most normal conditions.

PHASE I: The initial phase will focus on the synthesis and laboratory-scale characterization of PCM candidates. These materials must demonstrate a suitable phase transition at operational temperatures and possess the thermal mass necessary to sustainably absorb the heat generated during CC-SCBA operation. This phase will culminate in the delivery of a material sample along with a comprehensive analysis of its thermal performance under simulated operational airflow conditions.

PHASE II: Building upon the findings of Phase I, this phase will involve the integration of the PCM into a prototype CC-SCBA system. The material's performance will be validated in a controlled environment that replicates field conditions. Key performance indicators will include the PCM's ability to maintain a target inspired air temperature below 35°C, the duration of effective thermal regulation, and the material's regenerative capabilities after thermal cycling.

PHASE III DUAL USE APPLICATIONS: Collaboration with industry leaders in the CC-SCBA market will be essential to transition the PCM from a laboratory setting to a field-ready solution. This phase involves the design and production of a modular PCM component that can be seamlessly incorporated into existing CC-SCBA systems. The module must meet military specifications for durability, operational effectiveness, and ease of integration. Successful demonstration in this phase will lead to the exploration of dual-use applications, where similar thermal management challenges exist, such as in industrial respirators or high-performance athletic wear.

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KEYWORDS: protection, SCBA, closed circuit, phase change materials, thermal regulation, respirator

A24B-T015 TITLE: Distributed Multithreat Microsensor

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Integrated Sensing and Cyber, Microelectronics, Integrated Network Systems-of-Systems, Advanced Materials

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: Demonstrate a mission-configurable miniature, deployable sensing capability.

DESCRIPTION: Maneuver elements require early warning and situational understanding of the battlespace to include adversary actions and the threat of area denial tactics through the employment of hazardous persistent chemical agents. Soldiers are at risk of encountering dangerous circumstances as a consequence of having limited remote sensing capabilities for these situations. The joint forces require a small, lightweight technology that integrates with their equipment in a small form factor while affording prompt detection and reporting of the presence of multiple possible hazards or adversary troops and equipment in order to effect risk-based maneuver decisions and avoid hazards.

Emerging technology in miniature sensor science has increasingly demonstrated functionality and performance in the detection of hazardous chemicals and adversary movements and actions. Functionalized materials including metal oxide frameworks, carbon nanotubes, graphene, and conductive polymers have been reported with increasing sensitivity, selectivity, and reliability as environmental sensing modalities. Colorimetric technologies supply an inexpensive option for prompt and effective threat agent detection, and lend themselves to automation through the incorporation of color imagery or diode transduction.

PHASE I: Define a conceptual array of multimission sensing technologies for motion detection, equipment and personnel movements, and materials that deliver a unique response pattern for the presumptive detection of chemical warfare agents (CWAs) including G-, V-, H-, L-, A- series threat agents and pharmaceutical hazards like fentanyl and other drug-derived hazardous agents. Concepts for the sensing of such hazards and hazardous environments may include but is not limited to: magnetic, acoustic, passive infrared, and electromagnetic or electro-optical sensors, arrays of functionalized nanomaterials including metal and metal oxide particles and frameworks, single- and multi-walled carbon nanotubes, graphene, and colorimetric chemistries. The system concept should be modular to accommodate the means by which operators can configure the sensor array to meet a given mission priority (i.e., chem threat sensing or troop movements and actions as appropriate). Concepts should exhibit promising performance potential as evidenced by comparable reported performance testing or literature reporting on the recommended sensors and transduction mechanisms and the multivariate analysis approach that would yield reliable detection results.

PHASE II: Design, build, and test prototype sensor array that incorporates the proposed miniature sensors and functionalized materials onto an integrated compact device to demonstrate the proof of concept for the warning response in the presence of the aforementioned battlespace threat situations. Demonstrate proof of concept for the sensitivity of the array (identification/classification not required) to surface-deposited persistent chemicals and objectively demonstrate warning response. Further optimize the array performance and demonstrate its performance against each targeted hazardous situation. Devices should be amenable to form factors in the <200g range for the complete system including any battery mass, and operate for 8 hours or longer on a single charge. The starting Technology Readiness Level (TRL) on completion of the SBIR Phase II two-year Period of Performance should be TRL5 or greater, mandating the testing of the prototype under operational conditions and transduction mechanisms validated against live agents.

PHASE III DUAL USE APPLICATIONS: Integrate the prototype sensor array along with its electronic and physical packaging and software, and establish a manufacturing process for production of small production runs of scores of miniature deployable sensors. Establish a quality assurance procedure to validate the reliability, consistency, and reproducibility of the manufactured items. Phase III performance will likely involve the development of non-recurring engineering (NRE) for the production of consistent and reliable multifunctional sensor products. Support a test agency's operational test event and any user feedback events as opportunities present. Demonstrate the "as manufactured" the sensitivity of the array (identification/classification not required) to battlefield threat situations including adversary movements of personnel or equipment, chemical hazards including G-, V-, H-, L-, A- series threat agents and pharmaceutical chemicals, objectively demonstrate warning response. The starting Technology Readiness Level (TRL) on completion of the SBIR Phase III execution Period of Performance should be TRL6 or greater. Develop additional commercial products based on the final integrated system and pursue appropriate demonstration and testing opportunities.

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KEYWORDS: microelectronics, sensor arrays, mesh networked sensors, nanotechnology, transducers, electronic nose, pharmaceutical-based agents, chemical hazards

Version 2

A24B-T016 TITLE: Standoff Detection of Hidden Objects and Personnel In and Around Foliage

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Computing and Software, Integrated Sensing and Cyber, Integrated Network Systems-of-Systems, Human-Machine Interfaces

OBJECTIVE: Autonomous standoff detection of hidden objects and personnel in or around foliage at 50 feet to 250 feet.

DESCRIPTION: This Topic seeks technology capabilities to autonomously detect hidden objects and personnel in and around foliage and roadsides at standoff distances from 50 to 250 feet and provide a warning. Current commercial screening technologies include millimeter wave, terahertz sensors, magnetometers, x-rays, and in some cases neutron scattering. These technologies are effective at detecting target objects but are designed for near field detection (inches to feet). There is interest in detecting and tracking target objects at standoff distances of 50 to 250 feet for "agile node" such as expeditionary airfields, survivable command and control, agile support. The purpose of autonomy is to facilitate maneuver, enhance force protection, reduce cognitive and training burden on the operators. Autonomous detection and alarm reduce cognitive burden on operators by preventing screen fatigue and highlighting suspicious objects in a scene. Autonomous software can reduce training demands by supporting and assisting the operator during system start up and operation and suggest courses of action in response to a given alarm. Autonomy enables the operator to be located at a distance greater than 300 to 450 feet (the operator does not have to stay next to the sensor to see information and alarm) enhancing Force Protection. This Topic call does not include leave behind components such as point and vibration sensors.

PHASE I: Demonstrate detection of varying sizes and shapes of metal, plastics that are approximately the size of soup cans, gallon paint cans, small manhole covers, and personnel from distances of 50 feet, 100 feet, 150 feet, 200 feet, and 250 feet from a starting point on the ground representing sensor position to the target. If the sensor is positioned 30 feet in the air or on a post, as an example only, drop a line to the ground for the “starting point”. The objects and personnel should be placed in and around different types of foliage in spring, summer, fall brush, roadside brush, trees. Collect sufficient target data to develop and demonstrate feasibility for target object detection, classification, tracking using machine learning, artificial intelligence, signal processing innovations. Develop and deliver a sensor design that can be used to build a Phase II experimental prototype sensor that can be operated in a field experiment by a Government scientist, engineer, and Soldier. False alarms should be considered. Develop an approach that can be used to characterize system performance for detection and false alarms. An example would be to, but not limited to (NLT), develop a randomized or semi-randomized experimental design and test matrix that can be conducted within the budget boundaries of Phase I that can be used to provide data sufficient for preliminary limited receiver operator characteristics (ROC) curve(s) to demonstrate feasibility of sensor design concept. The purpose is to start thinking about false alarm states and mitigation. The Phase I deliverable should include both the sensor design and experimental data that supports the design and mitigates the Phase II risk. Offerings of market surveys and later down selection will be considered non-responsive.

PHASE II: Build and demonstrate a smart prototype sensor based on the design and algorithms developed in Phase I that can be operated by Government Scientists, Engineers, and Soldiers for the purpose of participating in an Army Expeditionary Warrior Experiment (AEWE) or equivalent user experiment. Collected target data in sufficient quantity to develop and demonstrate machine learning and artificial intelligence to scan, detect, classify, locate, and track target objects and personnel such that receiver operator characteristic curves (ROC) or similar statistical analysis can be developed to characterize system performance. The Phase II smart sensor should issue a visual alarm on a screen that an operator can see. The screen may be either a monitor screen attached to the sensor or a remote screen; one example would be, but not limited to, a cell phone. The prototype should demonstrate covert autonomous standoff detection from an agile node at 50 feet to 250 feet of a variety of metal shapes and personnel in and around foliage. Examples of an agile node might be expeditionary airfields, survivable command and control, or covert agile support. The prototype should demonstrate preliminary feasibility for operation on the move from a moving vehicle traveling 1 to 20 miles per hour. Using multiple sensors to scan surrounding area is acceptable. Innovations in machine learning and artificial intelligence may be used to scan, detect, classify, locate, and track target objects and personnel. The Phase II deliverable should be a prototype demonstration in contractor's facilities and a Warfighter experiment such as an Army Expeditionary Warrior Experiment (AEWE) or equivalent. The Phase II prototype sensor should be delivered "in place" to the Government. "In place" means that the prototype delivery will be in the Contractor's facility, but accessible for future work by the Government.

PHASE III DUAL USE APPLICATIONS: Further research and development during Phase III efforts will be directed toward refining the final deployable equipment and procedures. Design modifications based on results from tests conducted during Phase III will be incorporated into the system. Manufacturability specific to Counter Improvised Explosives Devices (C-IED) Program Concept of Operations (CONOPS) and end-user requirements will be examined.

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Version 2

KEYWORDS: standoff detection 20-250 feet, open unstructured environment, moving targets, millimeter wave, autonomous identification and tracking hidden threats and personnel

A24B-T017 TITLE: Artic Small-Unmanned Aerial System Automatic Ground Control Point Processing for Terrain Modeling

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Computing and Software

OBJECTIVE: Develop and validate an automatic Ground Control Point (Auto-GCP) methodology for orthomosaic and provide advancements in object identification & mapping (KAZE algorithms2) for multiscale feature detection.

DESCRIPTION: Small UAS platforms have redefined squad level ISR collection processes providing an overmatch capability, aiding in soldier lethality and maneuver for both dismounted and mounted off-road mobility platforms. In addition to the challenges of operating small UAS in Artic environmental conditions, the post processing of imagery for orthomosaic and DSMs (photogrammetric surface modelling derived from Structure from Motion) is complex due to the poor availability of identifiable ground features and contrast from a highly reflective surface. Traditional photogrammetry methods rely on GCPs and distinct terrain features to align and process imagery. However, in Artic environments that are characterized by flat, snow-covered terrain, lacking these critical features, rendering traditional methods less accurate and often incalculable. Recent computer vision and remote sensing advancements in object identification and mapping (KAZE algorithms2) for multiscale feature detection in nonlinear scale space will enhance photogrammetric accuracies as well as provide a basis to derive feature matching algorithms for localization in the absence on GNSS.

The goal of this topic is to further define photogrammetric processes unique to Polar Environments from small UAS imagery collections3,4. Those processes will result in automated, near real time product generation that will aid in ground maneuverability, UAS maneuver (obstacle avoidance) and visual terrain referencing for operations in denied GNSS environments.

PHASE I: Integrate and advance the photogrammetry process of automatically defining and matching ground control points (pre bundle adjustment) for accurate terrain modelling and imagery creation. Existing Auto-GCP algorithms will be integrated into the photogrammetric process in post processing of collected imagery to assess model performance on commercial hardware. The identified ground control points will be assessed for accuracies for inclusion in Visual Terrain Referencing in future resection algorithms for localization in GNSS denied environments. A detailed site survey will be produced with known ground control point horizontal and vertical accuracies that compares identified control points and benchmarked control points.

Determine atmospheric conditions in an Artic Environment that will support the desired final products at an absolute accuracy of minimum resolution of 10 centimeters with absolute geolocation accuracy of <5.0 m CE90/LE90 and vertical accuracy of <10 meters. An initial summary of results should include existing and derived results of weather affects on sUAS operations in artic environments. An approach will be established from surrogate or derived SUAS imagery or Full Motion Video for the efficacy of advanced high resolution terrain models and photogrammetric processes that are suitable for tactical level integration in military applications.

PHASE II: Develop a near real time computational process either on-board or via a direct down link to a End User Device that generates an orthomosaic of a pre-defined area and photogrammetrically derived DSM at a minimum resolution of 5 centimeters with absolute geolocation accuracy of <2.0 m CE90/LE90 (matching Artic DEM products) and vertical accuracy of <5 meters1. These 3D models will incorporate existing structure from motion and computer vision techniques employed by commercial and Army systems to derive ultra-high resolution 3D models. In addition to these products the near real time processing will also need to identify features in the environment that would be hazardous to UAS operations and flight mission planning.

The Auto-GCP algorithms will be fully integrated into the photogrammetric process and run in real-time during the collection phase. Existing algorithms will be incorporated into the photogrammetric processing that include recent advancements in feature detection and alignment and multiple scales (KAZE features9) available from existing automated geo-regristration techniques10.

PHASE III DUAL USE APPLICATIONS: This research will not only pave the way for accurate high-resolution mapping at the squad level in featureless terrain but will also provide methodologies for observing the rapidly changing Artic Environment. This application would also aid in climate change studies and environmental monitoring and assist in ground (mounted / dismounted) and low altitude SUAS maneuvers and flight operations where GNSS is limited or non-existent.

Commercial SUAS offerings in Arctic environments are limited due to the inability to operate above 60◦ latitude requiring a high-resolution Digital Elevation Model to launch and recover for terrain following. Commercial applications of this product will benefit from utilizing new data sets (Artic DEM Project) as well as advanced elevation models for flight planning and operations.

The primary development and integration effort for this phase will establish a near real-time localization algorithm and process for sUAS localization in the absence of GNSS post-initialization. A vision-based navigation or visual terrain referencing software system, encompassing the Phase II Auto-GCP software, will be established to use organically collected imagery and photogrammetrically derived DSM's for feature or horizon matching to determine the aircrafts position. The resulting localization will require an absolute position that is sufficient to carry out flight operations for a minimum of 50% of the entire flight time.
A real time object identification and avoidance model will be developed to aid in low altitude collections and reconnaissance missions derived from on-board optical camera systems. This effort will also aid in vision and terrain-based navigation with ground units for determining SUAS position and ground force localization during denied/degraded GNSS events.

The culmination of phase III will integrate the Android Team Awareness Kit (ATAK) 11 platform to render the resulting orthomosaics and DSM locally on device within 30 minutes of post flight operations. Final products will be delivered in a data format that already supported within the ATAK software suite and be properly aligned in a supported geographic data model (WGS 84 – Web Mercator).

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KEYWORDS: Auto-GCP, Small-Unmanned Aircraft Systems (SUAS), geolocation, Polar/Arctic environments

A24B-T018 TITLE: Biosynthetic PFAS Alternatives to Provide Omniphobicity

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Biotechnology, Advanced Materials

OBJECTIVE: Develop and scale production of biosynthetic materials for environmentally friendly, omniphobic technologies for Department of Defense clothing and equipment without use of fluorine or perfluorinated compounds (PFAS).

DESCRIPTION: The Department of Defense (DoD) uses finishes with perfluorinated compounds (PFAS) to provide essential properties for Warfighter protection and survival, including water, chemical, oil, and stain repellency for clothing and equipment items. PFAS, which are associated with cancer, reproductive health issues, and developmental delays, are being banned from use and manufacture worldwide. There are over 9,000 different PFAS compounds, used since 1940 in clothing, food packing, personal care products, water/stain resistant products, and non-stick cookware (1,2). Since PFAS have worked so well in providing water, liquid, oil, and omniphobicity, they have been the default chemicals used in the textile industry to provide the durable treatments needed to meet DoD clothing and equipment requirements.

The DoD is seeking new, biosynthetic and environmentally friendly non-PFAS technologies for clothing and equipment to impart omniphobicity. No PFAS-free alternative has been developed thus far which can provide the needed level of oil repellency, and while water repellency can be obtained, non-PFAS finishes struggle to meet military durability requirements over the expected life cycle of an item. Truly novel non-PFAS formulations/technologies are needed that can provide durable omniphobicity equivalent to those obtained using PFAS.

Biosynthetic materials are key to sustainable domestic production and offer new opportunities to discover and synthesize novel compounds (3,4). The goal of this topic is to solicit new biosynthetic material technologies that can replace PFAS compounds in DoD clothing and equipment, providing the needed level of oil repellency and durability. The developed non-PFAS bioinspired solution should target at least one of the following areas: textile-based systems clothing and equipment items (uniforms, shelters, sleeping bags, hydration systems), food packaging and/or protective clothing items (barrier materials) and be developed into a formfactor that can be integrated into an end item. The biosynthetic solution may be provided as an alternative coating or finish for an existing DoD item, or as an entirely new material or substrate with inherent repellency to replace and/or be integrated into existing materials within the DoD system. Integration into DoD end items must consider other requirements for the final product, such as retaining water repellency, flame resistant properties, or others.

Specific care must be taken to avoid “regrettable substitutions” such as siloxanes, which are under similar scrutiny as PFAS compounds from health and safety standpoints. Due to health, safety, and regulatory concerns, solutions should not contain any carbon-fluorine bonds, including partially fluorinated fluoropolymers, even those not defined as “PFAS” by the EPA. Thoroughly review state-of-the-art for non-PFAS substitutions and be familiar with environmental concerns for manufacture (such as the use of isocyanates or solvents) as well as feasibility of producing omniphobicity with the proposed system using environmentally friendly materials and processes (5).
(Suggested Reference: https://www.ri.se/en/popfree/pfas-substitution-guide-for-textile-supply-chains)

PHASE I: Feasibility Assessment: Demonstrate proof of concept for a biosynthetic solution with no fluorine-carbon bonds that can provide omniphobicity.
The objective is a small-scale demonstration of omniphobicity on a substrate to illustrate proof of concept.

Identify a biosynthetic system that can be synthesized and/or produced to provide omniphobicity. Achieving oil repellency is a greater challenge than water repellency using non-PFAS systems, but both qualities are critical for DoD clothing and equipment. Produce the bioinspired system at quantities over 10 grams (or milliliters), with an objective of 100 grams (or milliliters) and a purity over 80%.

For textile substrates, feasibility can be demonstrated on a swatch or coupon by achieving some level of oil repellency in accordance with the American Association of Textile Chemists and Colorists (AATCC) Test Method 118. Water repellency can be demonstrated through spray rating tests (AATCC Test Method 22), and at this stage should prove water repellency can be achieved in addition to oil repellency using the proposed omniphobic system. If a demonstration on a swatch or coupon cannot be performed during Phase I, a robust model demonstrating how the synthetic biology technology will impart omniphobicity must be provided, with a realistic path towards application on a DoD end item.

An assessment of scaling capability for the omniphobic technology will be made, with special consideration for industry standard practices and limitations, and any benefits of using biotechnology for environmentally friendly manufacture. At the completion of Phase I, a sample of the non-PFAS technology proposed must be made available for independent evaluation by the Government Technical Point of Contacts. If a small-scale demonstration was performed, a sample of these materials should be provided for independent evaluation as well.

Prior to moving into Phase II, the specific targeted application and/or properties expected of the solution should be identified.

PHASE II: Prototype Development: At the end of Phase II there should be a viable solution to provide durable omniphobicity to a DoD end item. The technology should be scalable to commercial levels.

Year 1: Optimization and application of the biosynthetic technology on the targeted substrate and/or application into a DoD end item.

The biosynthetic technology should be scaled to an appropriate level that it can be applied to a DoD end item. Partnership with a manufacturer is encouraged. The scaling method should consider environmentally friendly practices, including use of biotechnology and solvent-free systems. Application or integration of the biosynthetic solution into the DoD clothing or equipment should be determined based on the formfactor of the solution and requirements of the end item. Regardless of formfactor and integration/application method, end items should maintain the desired physical properties as determined by the end use application. For example, weight, thickness, air permeability, durability to abrasion and laundering, etc. for textiles used for personal clothing and equipment items, resistance to cold cracking for shelters application, durability to delamination in food packaging, no leaching etc. The omniphobic solution should not impart more than a 10% weight gain to the end item.
Testing will be performed based on the end use application and properties identified. Oil repellency on textile substrates should be determined in accordance with AATCC TM 118. A 5A oil rating should be achieved, with an objective of higher oil ratings up to 8A (per AATCC TM118). These oil rating values reflect lowered surface energy of the substrate that protects against fuels and battlefield contaminants such as F-24. Spray rating test AATCC TM 22 should be used to determine water repellency on textile substrates. As oil repellency presents the larger challenge, a demonstration that the omniphobic technology can provide water repellency in addition to meeting oil repellency metrics is sufficient.

At the end of year 1, at least 4 sample swatches a minimum of 6 x 6 inch, or one completed prototype incorporating the optimized omniphobic technology should be delivered to the Government Technical Point of Contacts for independent evaluation, along with a report detailing the technology development in detail, all test data and evaluations conducted to verify that the target performance criteria is met, and a feasibility assessment for scaling up the omniphobic technology.

Year 2: Ability to scale repellent technology.
Lab scale production to 1000 grams (or liters) for industry scale up should be achieved, prioritizing environmentally friendly practices. Work with a manufacturer to scale up the biosynthetic technology to commercial levels and determine a realistic pathway to integrate with the DoD end item. Special consideration should be made to maintaining the DoD end item functionalities – for example, water repellency, flame resistance, dyability. By the end of Year 2, pilot production level quantities of the biosynthetic solution will be achieved in a formfactor and purity level acceptable for manufacture (as determined by standard practices for the targeted DoD end item manufacture). Partnership with a manufacturer is encouraged.

Treated end items at a pilot or prototype scale level must be supplied to the Government Technical Point of Contacts for independent evaluation: 1 yard of a treated fabric substrate, laminate, membrane, or similar material; or 1 prototype of the treated end item (ex. shirts, gloves, sleeping bags, hydration systems). A cost analysis for producing the end items at full scale production is required at the end of Year 2, as well as a durability assessment for the lifecycle of the finished end item predicting durability to laundering, abrasion etc.

PHASE III DUAL USE APPLICATIONS: Commercialization: Proposals should establish a lifecycle framework that can mature as the technology or process advances through the acquisition process. Life cycle management is an important consideration when assessing the potential PFAS release into the environment from manufacturing through use (including abrasion during wear and laundering) and disposal. At end-of-use, any residual chemistry needs to be handled in the relevant material recovery method, regardless of whether it is recycling, incineration, or landfilling. Contamination can occur in:

- Ground/Water - carpet and clothing are most likely sources of PFAS in landfill leachate.
- Air - During manufacturing air emissions from volatile substances must be addressed. PFAS that is polymerized and integrated into the textile, when thermally decomposed such as in burn pits, could also be released into the environment. Burning waste in pits can create more hazards compared to controlled high-temperature burning - like in a commercial incinerator.
- Water – The processing/manufacturing of textiles containing PFAS can lead to wastewater contamination (water emulsions during application to fabrics, effluent water). Many textile manufacturers (Milliken, DuPont, 3M, and Mount Vernon Mills) have been sued for contaminating US public drinking water.

Synthetic biology systems using biomanufacturer for production may offer greener alternatives and reduce environmental contamination.

There are 100 plus DOD items which have been identified as using PFAS to meet omniphobicity requirements in end item applications including many cold weather clothing items. In addition to supporting the Army's Arctic Strategy and the Army's Climate Strategy, the technology developed will be applicable to a variety of items currently in the supply chain. Depending on the technology developed it could benefit clothing and equipment items the Army Overwhite program, ECWCS (Extended Cold Weather Clothing System) and CTAPS (Cold Temperature and Arctic Protection System,), clothing items and/or shelters used to provide chemical and biological protection and other items used for a specific MOS such as fuel handler coveralls etc. where omniphobicity is crucial to provide required protection or food packaging items
The developed technology would provide dual-use applications in the civilian sector in the high end outdoor retail clothing industry, but perhaps more importantly in protective personal equipment for first

responders and healthcare workers in addition to the possibility of replacing PFAS currently used in medical devices all of which have been impacted by PFAS regulations and restrictions.

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KEYWORDS: PFAS; Synthetic Biology; Bioinspired; Clothing and Equipment; Omniphobicity; Non fluorinated

A24B-T019 TITLE: Additive Manufacturing for Protective Eyewear

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Materials

OBJECTIVE: Develop materials and an approach to manufacturing ballistic protection eyewear lenses with integrated prescription correction that is also suitable for point-of-need additive manufacturing.

DESCRIPTION: Combat eye protection is a ubiquitous need for all deployed Soldiers. The eyewear provides the wearer protection against ballistic-fragmentation and environmental concerns, like blowing sand, while remaining transparent to retain situational awareness. Protective eyewear lenses are currently made via injection molding and are not easily customized to provide vision correction. Any needed prescription vision correction is currently achieved with the Universal Prescription Lens Carrier (UPLC).[1] The UPLC sits behind the primary protective lens and contains a separate set of corrective lenses specific to the User's vision correction needs mounted into the UPLC frame. This creates integration issues for equipment worn on the face and eyes and limited field-of-view through the prescription lenses in addition to adding substantial logistical burden. The Army product manager for Soldier Protective Equipment (PdM SPE) has an ongoing initiative to identify technologies that would allow the elimination of a separate vision corrective lens (I.e. an integrated vision correction / ballistic protection lens). These lenses are expected to have a life cycle of less than six months since ballistic eye protection lenses are often rapidly degraded in combat environments due to scratching and abrasion.[2] Therefore, it is also desirable to have rapid turnaround on individually customized corrective lenses and to limit the logistics burden by providing manufacturing capability that is close to the point-of-need as well as being customizable to an individual wearer. An additive manufacturing (AM) method is most likely to meet these requirements. As AM technology has progressed, printing resolution and material development have improved to the point where optically clear samples are now achievable.[3] The cost of this technology has also decreased to being a commercially viable approach to manufacturing custom lenses. Companies in this space are continuously developing new materials for their 3D printers to impart performance that has only previously been attainable with conventional manufacturing methods. Significantly, the expanded use of augmented reality (AR) in both military and civilian sectors has spurred advances in optically clear and durable eyewear manufactured with AM.

The goal of this topic is to develop materials and processes to rapidly manufacture a customized ("one off") optical lens that meets all requirements of MIL-PRF-32432A for ballistic protection lenses as well as providing excellent optical quality, dimensional tolerances, and stability in all environments sufficient to provide vision correction.

PHASE I: Develop the materials and additive manufacturing processes needed to fabricate flat plaques that are optically transparent (>89% luminous transmittance, with less than 3% haze and minimal optical distortion) yet provide ballistic protection as outlined in MIL-PRF-32432A.[4] It should also be demonstrated that the cured plaques remain optically transparent and maintain impact resistance across a range of humidity (35-95% ± 5%), temperature (-60 °F - +160 °F), exposure to solar radiation and common military chemicals to include: 6.0 % by weight sodium hypochlorite, insect repellent-controlled release diethyl toluamide (30% concentration DEET), fire resistant hydraulic fluid (MIL-PRF-46170), hydraulic fluid, petroleum base (MIL-PRF-6083), gasoline (87% octane), motor oil (SAW 10W-30) and F24 fuel (NATO Standard AFLP 3747), as well as resistant to scratching/abrasion, and be resistant to fogging, as required by MIL-PRF-32432A for currently fielded protective eyewear. Some possible candidate materials to achieve this balance include acrylics, urethanes and polycarbonates. Companies making and selling 3D printers and resins may not fully specify the formulation of their products due to proprietary restrictions so in-house resin development may be necessary.

PHASE II: Optimize materials and processes that allow for AM of optical quality structures that meet minimum MIL-PRF-32432A requirements for luminous transmittance, optical clarity and ballistic performance as outlined in MIL-PRF-32432A for military eyewear. The materials should be compatible with standard commercial-off-the-shelf AM systems (dynamic light projection, stereolithography, etc.) without needing customization. Printing of eyewear lens prototypes should be achievable in less than three hours with sub-100 µm printing resolution and allow for printing of a "one-off" lens that demonstrates custom vision correction. Demonstrate the optical transparency and ballistic protection of the resulting cured eyewear prototypes and the fidelity of the printed, cured part to the original design. Parts should be printed to demonstrate the utility of this approach by printing a range of lenses with incorporated vision correction covering a range of –10.00 to +8.00 diopters with up to -3.25 diopters of cylinder. Example lenses shall at a minimum include prescriptions at +8, -10, +5, -5, +1.5,-1.5 diopters as well as a non-prescription optically corrected variant for comparison. Prescriptions shall be reasonably accurate (within 0.25 diopter) as measured on a lensometer. Lens designs shall maximize field of view through the lens, and offer peripheral protection. It is highly encouraged that offerors partner with a protective eyewear supplier early on in the effort. [5]

PHASE III DUAL USE APPLICATIONS: The development and maturation of this technology will allow for integrated sensory protection and vision correction for the wearer. This advancement will enhance situational awareness of the wearer by enabling customization for optimal vision correction not currently available in fielded products. It also reduces the logistical burden and timeframe needed for replacement lens to reach point-of-need, and supports the DoD's National Defense S&T strategy to create and field capabilities at speed and scale through innovation of industrial processes.[6] With this technology, there is significant benefit to the civilian sector for not only protective eyewear, but eyewear in general. The customization achievable with this approach would ensure wearers of every head size, shape and prescription could obtain the best vision correction possible. [7] Specifically the safety, sports and augmented reality areas would benefit from this technology development.

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KEYWORDS: Additive manufacturing; Ballistic protection; Eyewear; Optically transparent; Vision correction; Multifunctional; Integrated protective eyewear; Combat eye protection; Authorized protective eyewear list (APEL)

Version 2

A24B-T020 TITLE: Drone Swarm Detection Using Artificial Intelligence Based on Ultrafast Neural Networks

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Computing and Software

OBJECTIVE: Drone swarm detection using Artificial Intelligence. Develop a neural network architecture, and learning processing algorithms for drone identification based on ultra-fast neural networks with low power consumption.

DESCRIPTION: The goal of this Army Small Business Technology Transfer (STTR) topic is the identification of airborne drones from their radio frequency transmissions or radar signatures using ultra-fast neural networks [1]. The drone identification and classification are done by rapidly analyzing RF signals from one or several receiving antennas. As several target drones are often present in the antenna's range, the received signal may represent a result of interference of several sources. For such a multiple target identification in a drone swarm, it is crucial to be able to process information in parallel and directly at the carrier microwave frequency.

Recent research into applications of artificial intelligence (AI) based on neuromorphic networks (in particular, using magnetic artificial neurons [1-5]) was executed to solve a variety of computational and signal processing problems. The purpose of neuromorphic computing is to replicate the human brain functionality in nanoscale using man-made neurons and synapses. The advantage of this approach is highly parallelized computing with large amounts of memory in close proximity to the computing elements, which results in a substantially increased speed and reduced power consumption of computing.

The methodologies described in [1-5] are particularly suited for defense-related computing due to a number of unique features, such as nano-scale sizes, simple implementation of memory elements and strongly nonlinear dynamics. Of a particular interest for military applications is the low power consumption of the network elements, and possibility of operation in GHz [2, 3] and even THz [4, 5] frequency ranges. These high-frequency properties allow one to utilize neural networks for parallel processing of drone microwave signals at the carrier frequency without digitization or super-heterodyning.

Another important consideration in the drone identification problem is the power requirements of the device. Recently, it has been demonstrated [6], that neural networks based on artificial antiferromagnetic neurons are capable of performing simple identification tasks in sub-nanosecond time with extremely low power consumption of less than 1 pJ per synaptic operation. These results look very promising for the development of mobile ultra-fast and low-power devices for neuromorphic identification of drones.

The goal of this call is to develop a neural network capable of simultaneous ultra-fast (time scale of nanoseconds) identification and targeting of large groups (swarms) of drones threatening ground vehicles. Another goal is to design an optimal architecture of an ultra-fast neural networks with integrated memory, and to develop and test learning and data-processing network algorithms suitable for ultra-fast detection of multiple drones in a drone swarm.

PHASE I: Using computer simulations, demonstrate the possibility of using artificial intelligence in the form of an ultra-fast neural network for processing multiple microwave drone signals without super-heterodyning or/and digitization. Demonstrate possibility of classification of drone microwave signals using ultra-fast neural networks in a case when the input signals from drones are monochromatic (unmodulated).

PHASE II: Determine optimum materials for the development of ultra-fast, lower power consumption neural networks. Develop principles of building large neural networks that will utilize ultra-fast processing capabilities of the chosen network elements (artificial neurons). Develop and test learning algorithms for drone identification in the presence of a single and multiple (2-5) drone signatures and modulated drone signals. Using computer simulations, demonstrate successful drone classification using a developed ultra-fast neural network. Determine processing time, power consumption, weight and size of an anti-drone device based on neural networks.

PHASE III DUAL USE APPLICATIONS: Demonstrate successful drone identification using an experimental prototype of a developed neural network. Demonstrate possibility of simultaneous identification of multiple drone targets. Potential applications include: light weight, ultracompact antenna for use in reconnaissance and observation drones (commercial and military); real-time monitoring of frequency agile microwave K band signals with potential applications to Active and Passive protection systems. Commercial application: Autonomous driving platforms and radar-based collison avoidance systems.

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KEYWORDS: artificial intelligence, ultra-fast, artificial neuron, drone identification, learning algorithm