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

The approved 23.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 25-26 April 2023 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 $197,000.00 over a period not to exceed six (6) months. **PLEASE**

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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.

The Army has established a **10-page limitation** for Technical Volumes 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, or the CCR. The Technical Volume 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 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. 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 an 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/schedule/. 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: Proposal Cover Sheet, Technical Volume, Cost Volume, Company Commercialization Report, Supporting Documents, and 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.**

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 $1,315,000.00. **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 $657,500.00; the second 12 months of funding should also be approximately $657,500.00. The entire Phase II effort should not exceed $1,315,000.00. 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 $657,000.00 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 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. 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 DEBRIEFS

Once the selection process is complete, the Army STTR Program Manager will send an email to the "Corporate Official" listed on the Proposal Coversheet with an attached notification letter indicating selection or non-selection. Small Businesses will receive a notification letter for each proposal they submitted. The notification letter will provide instructions for requesting a proposal debriefing. The Army STTR Program Manager will provide ***written*** debriefings upon request to offerors in accordance with Federal Acquisition Regulation (FAR) Subpart 15.5.

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 **$197,000.00** 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: Proposal Cover Sheet, Technical Volume, Cost Volume, Company Commercialization Report, Supporting Documents, and Fraud, Waste, and Abuse.

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 23.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	Dawn.m.gratz.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	Scotty Vincent Eric Johnson	Scott.h.vincent4.civ@army.mil Eric.s.johnson212.ctr@army.mil

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Army STTR 23.B Topic Index

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A23B-T001 TITLE: Passive Ranging for Fire Control under Day and Night Conditions

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: Design and build a system that can passively range to operationally relevant distances in daylight, low light, overcast and night conditions.

DESCRIPTION: To date much work has been invested in active ranging. However, laser-based probes are detectable and will leave the operator vulnerable, particularly at night.
Commercial applications, particularly those for self-driving vehicles, use a combination of both active and passive sensors. Low light imagers have been recently announced, that span both the VNIR, and SWIR and some are even capable of single photon detection. These low-light detectors are likely intended for the automotive market. Many, but not all have resolutions approaching HDTV. They offer, either through correlation or key-point signature comparisons a way to determine range covertly in what until now has been consider challenging situations. Passive ranging is a desired new capability for our individual soldiers and for military platforms. It is not in any currently fielded system. Providing a measured range accuracy of +/- 20 meters at 300 meters is adequate for a proof-of-concept demonstration.

PHASE I: Develop overall system design that includes specifications for ranging to distances of 100 meters, 300 meters and 1km. State the possibilities and challenges to achieving those ends including estimates of uncertainties in range. Consider both GPS and GPS denied regions of operations. Accuracy goals should be approximately +/- 20 meters at 300 meters with a linear increase to +/- 60 meters at 1000 meters.

PHASE II: Develop and demonstrate a prototype system in a realistic environment. Conduct testing to prove feasibility over extended operating conditions. Accuracy goals should be approximately +/- 20 meters at 300 meters with a linear increase to +/- 60 meters at 1000 meters.

PHASE III DUAL USE APPLICATIONS: This system could be used in abroad range of military and civilian applications where ranging and tracking are necessary. Optimize system design for size, weight and power, to include ruggedization to survive in a military environment.

REFERENCES:

1. Fitzgibbon, A. (2001). Simultaneous linear estimation of multiple view geometry and lens distortion. CVPR, IEEE Computer Society Conference on Computer Vision and Pattern Recognition. Kauai, HI Dec8-14: IEEE. doi:0.1109/CVPR.2001.990465

2. Hartley, R. (2003). Multiple View Geometry in Computer Vision. Cambridge, England: Cambridge University Press. doi:isbn-13 978-0-521-54051-3
3. Yang, J. (2020) Z. Lu, Y.Y. Tang, Z. Yuan and Y. Chen; Quasi Fourier-Mellin Transform for Affine Invariant Features; IEEE Transactions on Image Processing, Vol. 29, 2020
4. Reilly, P. (1999) T. Klein, and H. Ilves; "Design and Demonstration of an Infrared Passive Ranger"; Johns Hopkins APL Technical Digest, Vol 20, No. 2, pp. 220-235, 1999.
5. Tomasi (1992), Carlo and Kanade, Takeo; Shape and Motion from Image Streams under Orthography: a Factorization Method"; International Journal of Computer Vision; Vol 9, no 2, pp. 137-154.
6. Pelegris, Gerasimos (1994); "A triangulation Method for Passive Ranging"; Master's Thesis Naval Postgraduate School; Monterey California. DTIC AD-A284 180
7. Range finders and Tracking; Summary Technical Report of Division 7, National Defense Research Committee; V. Bush, Director; J.B. Conant, Chairman; H.L. Hazen, Division 7 Chief; 1947

KEYWORDS: passive ranging, low-light, key-points, correlation.

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A23B-T002 TITLE: Thermal Protection Coating for Artillery Projectiles

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

OBJECTIVE: Develop innovative conformal, ruggedized solutions for thermal protection of extended range artillery rounds.

DESCRIPTION: The Army's Long Range Precision Fires mission expands the current portfolio of conventional artillery to advanced munition technologies with extended range capability (>70km). Extended range requires the projectile to fly to higher velocities and altitudes as well as longer flight times. At high Mach speeds the projectiles may be exposed to high temperatures and heat fluxes up to 3500°C and 1000 W/cm2 respectively. These are new environments to which conventional gun launched ammunition has not been subjected to. Along with qualifying artillery for new weapons platforms such as Extended Range Cannon Artillery (ERCA), they also have to survive the extended range environment. The Army is currently looking for novel thermal protection coatings for artillery shells in an effort to extend the capability of conventional ammunitions and enable integration of other aero-structural materials such as polymer matrix composites and high strength alloys. The proposed solution must be able to protect the underlying base material against high heat flux and high temperature damage. The technology should be capable of surviving typical artillery gun launch loads and should conform to the geometry of an artillery projectile.

PHASE I: During the Phase I contract, successful proposers shall conduct a proof-of-concept study that focuses on thermal protection coating technologies that can withstand and operate within varying thermal loads ranging from 5 W/cm2 to 700 W/cm2 and temperatures ranging from ambient to 2000°F (objective) for up to 5 minutes (objective). Coating thickness should not exceed 5mm (objective) and can be ablative in nature so long as sufficient thermal protection is sustained to meet the objectives. Investigations should include analysis of material performance under transient thermal loading and thermos-structural performance of a coated Inconel steel substrate. A final proposed concept design, including a detailed description and analysis of potential candidate coating technology is expected at the completion of the Phase I effort.

PHASE II: Using the data derived from Phase I, in Phase II the proposer shall fabricate and integrate a prototype of the technology into a nominal projectile form-factor. The proposer shall further their proof-of-concept design and determine the applicability of the coating for different surface materials. Upon evaluation of the design through a critical design review, the prototype hardware's survivability shall be demonstrated via high G testing (35,000 G objective) in an air launched munition and aerothermal ground testing. Information and data collected from these tests will be used to validate operational performance.

PHASE III DUAL USE APPLICATIONS: Phase III selections shall identify large scale production alternatives and fabricate 20 prototypes that can be integrated into a nominal projectile form-factor to be identified by the SBIR: Army 20 Topics and Concepts Government. Live fire tests will be conducted, and the prototype integrated with projectile form-factor will have to withstand shock loads approaching 35,000g's. Phase III selections will develop of a cost model of expected large scale production to provide estimates of non-recurring and recurring unit production costs. Production concept for commercial application will be developed addressing commercial cost and quality targets. Phase III selections might have adequate support from an Army prime or industry transition partner identified during earlier phases of the program. The proposer shall work with this partner (TBD) to fully develop, integrate, and test the performance and survivability characteristics of the design for integration onto the vendor’s target platform.

REFERENCES:

1. Abdul-Aziz A. Durability Modeling Review of Thermal- and Environmental-Barrier-Coated Fiber-Reinforced Ceramic Matrix Composites Part I. Materials (Basel). 2018;11(7):1251
2. Eugenio Garcia,Reza Soltani,Thomas W. Coyle,Javad Mostaghimi,Angel De Pablos,Maria Isabel Osendi,Pilar Miranzo, Thermal Behaviour of Thermal Barrier Coatings and Steel/Thermal Barrier Coatings Structures, Advances in Ceramic Coatings and Ceramic-Metal Systems: Ceramic Engineering and Science Proceedings, Volume 26, Ceramic Engineering and Science Proceedings, 2005
3. Padture N. P.; Gell M.; Jordan E. H. (2002). "Thermal Barrier Coatings for Gas-Turbine Engine Applications". Science. 296 (5566): 280–284.
4. Clarke, D.R.; Oechsner, M.; Padture, N.P. Thermal-barrier coatings for more efficient gas-turbine engines. MRS Bull. 2012, 37, 891–898

KEYWORDS: Thermal Protection System, Advanced Materials, Artillery, Conformal Coatings, Hypersonics, Extreme Environments

VERSION 3

A23B-T003 TITLE: Optical Computing Network

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy, Microelectronics, Integrated Network System 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 section 3.5 of 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: Design and build a programable optical network equivalent to an electrical network to solve Markovian graphs with cycles. Forney-style factor graphs can be solved while avoiding the creation of trees.

DESCRIPTION: The use of digital image processing to enable target detection, classification, recognition and identification, as well as targe state estimation for fire control solutions is computationally intensive. It requires significant processing power, which in turn requires significant electrical power. A programable optical network can be used to perform these computations at reduced Size weight and power and at faster speeds. Factor graphs have been used to describe Bayesian networks (Pearl, 1988) and were applied to SLAM (Simultaneous Location and Mapping) by Dellaert (2017). These problems tend to be decomposed into trees for solution.

The most general graph, and the one that is most difficult to solve, is the undirected graph with cycles. This is related to quantum computing and such difficult logistical problems such as the travel salesman conundrum.

It is desirable to try to develop a room temperature solution, based on optical networks, that can at least reliably solve all convex Kalman filter problems.

PHASE I: Design and develop programable optical circuit elements that map the nodes in a factor graph to those of an optical network much as Vontobel did for electrical components.

PHASE II: Develop and demonstrate a prototype system consisting of the optical elements to create a network that can solve a problem.

PHASE III DUAL USE APPLICATIONS: Build an integrated optic that can be deployed that can implement a Kalman filter with real world application.

REFERENCES:

1. Dellaert, F. (2017). Factor Graphs for Robot Perception; Foundations and Trends in Robotics, Vol 6. No. 1-2 (2017) 1-139; DOI: 10.1561/2300000043
2. Pearl, J. (1988), Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference; Morgan Kaufmann Publishers Inc. San Francisco Calf; ISBN 1-55860-479-0

3. Vontobel, P.O.; Factor Graphs, Electrical Networks, and Entropy; http://www.isiweb.ee.ethz.ch/papers/arch/pvto-dlip-aloe-2002-mtns.pdf
4. Vontobel, P.O.; Kalman Filtering, Factor Graphs and Electrical Networks. http://www.isiweb.ee.ethz.ch/papers/arch/pvto-dlip-aloe-2002-mtns.pdf
5. Wang,S. (2020); A Factor Graph-Based Distributed Consensus Kalman Filter; IEEE Signal Processing Letters, Vol 27, 2020.

KEYWORDS: Graphs, networks, Kalman Filter, trees, cycles.

A23B-T004 TITLE: Metal Powder Based Additive Manufacturing for use in Portable System in an Expeditionary Environment

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Infrastructure & Advanced Manufacturing, Sustainment & Logistics

OBJECTIVE: Develop a metal powder based additive manufacturing system suitable for deployment in expeditionary environments to manufacture complex metal components with minimal post processing requirements to support contested logistics scenarios.

DESCRIPTION: The current state of the art utilizes conventional manufacturing technologies such as computer numerical controlled (CNC) machine tools such as mills, lathes, and plasma cutters, which are augmented by various manually operated metal working machines to fabricate metal components. Depending on the component, this process can involve numerous steps to achieve complex features necessary to meet specifications. Additionally, operators require significant skill levels to operate these machines effectively and efficiently in order to rapidly produce components. This all adds up to cumbersome, inefficient approaches to sustain materiel in the field.

Compared to conventional manufacturing technologies, additive manufacturing (AM) is the revolutionary process of creating three-dimensional objects by the successive addition of material which starts with a digital model, usually generated by computer-aided design (CAD)1. AM introduces a new design paradigm that allows the fabrication of geometrically complex parts that cannot be produced by traditional manufacturing and assembly methods2. Furthermore, AM can expedite fabrication of complex components which require extensive skills and many operations to achieve using conventional methods, reducing time to product and therefore the buy-to-fly ratio3. One particular AM process is Metal Powder Bed Fusion (PBF), which, per internal government research, may be ideal to manufacture complex metal components to enable agile sustainment of armaments systems in expeditionary environments.

While metal PBF may be the optimal AM process for DoD mission needs, it comes with many risks and challenges. First and foremost, the high surface-to-volume ratio of powder particles coupled with the reactive nature of these metals means that special care must be taken when handling them. Powder explosions are unfortunately still a regular occurrence internationally and these often result in serious injury and loss of life4. Therefore, minimizing handling of powdered metal materials is essential to safe operations. Possible approaches include but are not limited to automation of part excavation and powder reclamation and/or use of material cartridges to eliminate manual powder loading. Another challenge is the requirement for an inert atmosphere for the PBF process. The role of the inert atmosphere during powder bed fusion (PBF) is to remove the process by-products and the air that is initially present in the process chamber5. By today's standard, Argon is most common with laser processing. Nitrogen is also an option which could minimize logistical burdens by allowing use of a Nitrogen generator but, thus far, this option limits print quality for certain materials5. One possible approach to overcome this challenge might entail process development to utilize vacuum in place of gas to achieve the inert atmosphere, which has had success with electron beam processing.

PHASE I: Research, modeling, and simulation of novel approaches to improve PBF machine processes, design, and other considerations including but not limited to safe powder storage, handling, and processing to reduce or eliminate exposure to powder materials during material loading or unloading and part excavation, alternative strategies to inert chambers to decrease dependence on process gases, and increased survivability of equipment during transport over rugged terrain (MIL-STD 810). Collaboration between government, industry, and academia will further develop and refine requirements. Develop a test plan for mechanical properties and metallurgy to establish a baseline upon which improvements can be made through process development in follow-on work.

PHASE II: Development and engineering of metal PBF AM equipment resulting in a functional prototype which meets requirements developed during Phase I and is proven through extensive testing. Test results must prove that the developed machine can operate in austere conditions with maximum operator/facility safety and minimal logistics requirements while surviving exposure to the military field environment. Testing of materials to determine baseline mechanical and metallurgical properties should be executed and well documented.

PHASE III DUAL USE APPLICATIONS: The development of metal PBF AM machines to meet this mission requirement will augment sustainment capabilities in austere conditions with more rapid technologies able to produce a broader spectrum of components when compared to the current state of the art. Additionally, this effort has potential for applications in the oil and gas industry to enable enhanced facility and equipment sustainment on-site which can allow continued operations and sustained production rates. Follow-on work should focus on certifying materials through process development to produce qualified application-critical weapon system components.

REFERENCES:

1. American Society for Testing and Materials, ASTM ISO/ASTM52900-21 Additive Manufacturing – General Principles – Fundamentals and Vocabulary, https://www.astm.org/f3177-21.html (accessed 31 OCT 2022).
2. McCarthy, D.L. & Williams, C.B.. (2012). Creating complex hollow metal geometries using additive manufacturing and electro forming. 23rd Annual International Solid Freeform Fabrication Symposium – An Additive Manufacturing Conference, SFF 2012. 108-120.
3. Rasiya, Gulnaaz & Shukla, Abhinav & Saran, Karan. (2021). Additive Manufacturing-A Review. Materials Today: Proceedings. 47.
4. Benson, J.M.. (2012). Safety considerations when handling metal powders. Journal of the Southern African Institute of Mining and Metallurgy. 112. 563-575.
5. Pauzon, Camille & Hryha, Eduard & Forêt, Pierre & Nyborg, Lars. (2019). Effect of argon and nitrogen atmospheres on the properties of stainless steel 316 L parts produced by laser-powder bed fusion. Materials & Design. 179. 107873.

KEYWORDS: additive, manufacturing, laser, electron, beam, metal, powder, expeditionary

VERSION 3

A23B-T005 TITLE: Joining of Dissimilar Materials for Hypersonic Applications

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): 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 section 3.5 of 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: A methodology or methodologies to join ultra-high temperature ceramics to a variety of dissimilar substrate materials such as carbon-carbon, ceramic matrix composites and lightweight metals.

DESCRIPTION: The U.S. Army must develop highly maneuverable hypersonic weapons that can survive high-G shock loads and harsh aerothermodynamic environments in a GPS-denied environment. To enable these requirements new materials and new manufacturing methods must be developed. There has been increasing desire to develop vehicles and projectiles that travel at the speed of sound and beyond. Materials with melting temperatures of 2000C and higher, ceramics based on silicon carbide (SiC) and silicon nitride (Si_3N_4) as well as carbon-carbon (C-C) composites, were developed and investigated to handle the aerothermal heating experienced at nose tips and leading edges of vehicles traveling at these velocities. The desire to push velocities into the hypersonic regime requires the development of materials with oxidation resistance and thermomechanical properties that can handle aerothermal heating to 3000C. The temperature requirement alone severely limits the available materials. Carbides and/or borides of hafnium (Hf), zirconium (Zr), titanium (Ti) and tantalum (Ta) fall into this category as do composites based on these materials and potentially high-entropy ceramics (HEC) that are multicomponent ceramics. While these materials meet the necessary temperature requirement and significant effort has been made in improving the properties at these temperatures the geometric complexity of the components as well as the cost associated with the manufacturing these materials it is currently impractical to expect these materials to be employed as monoliths in this application. What is more likely is the development of components comprised of multiple materials. Ceramic matrix composites (CMCs), C-C, and lightweight metals could be used as the structural component and can be produced cost-effectively and with the necessary geometric complexity while a UHTC layer on top of the component will protect the structural material from the extreme environments experienced during hypersonic flight. This will only work if these dissimilar materials are properly joined together to take fully take advantage of the benefits of these vastly different materials. The need to join dissimilar materials is not new. Methods such as welding, brazing and solid-state joining have been explored to create innovative ceramic/metal systems that result in improved impact resistance or that can function in advanced diesel and turbine engines as well as a variety of other applications. Success has been limited as a major challenge has been overcoming the residual stresses that develop at the interface due to the significant difference in thermal expansion of the materials. These residual stresses, if not property controlled, lead to generated of cracks and damage that lead to property degradation and reduced reliability of the joint. The focus of this effort will be the development of cost-effective methodologies to join these dissimilar materials to produce multi-material components that can survive the extreme environments encountered during launch and hypersonic flight. The focus will be on joining an ultra-high temperature ceramic to a carbon-carbon composite. A potential advantage over previous joining attempts is that the thermal expansion coefficient of these materials can be tailored to minimize or control the level of residual stress in the system increasing the likelihood of the success.

PHASE I: The offerer will demonstrate a method or methods of joining a UHTC (preferably a ZrB2-SiC composition) to a C-C composite and/or a Zr metal substrate. Treating the UHTC and/or substrate surface and/or the use of a filler material(s) between the UHTC and substrate to promote joining are permitted. At a minimum the following will be performed:

- Microstructural characterization of the joint area to determine the extent and quality of the interface including the edges of the interface as well as identifying any damage to the UHTC or substrate that may have occurred due to the joining process,
- Measurement of residual stresses that develop at the interface as well as in the UHTC and the substrate material,
- Mechanical characterization of the UHTC/substrate joints at room temperature to determine the interfacial tensile and shear strength,
- Perform fracture analysis of the mechanically tested specimens to assess joint quality and identify the failure process,
- Determine the oxidation resistance of joined UHTC/substrate materials at temperatures up to 1200C, and
- Perform thermal shock testing by heating the joined material to 1200C followed by a rapid quench to room temperature in water.

A successful joining method will be one where the room temperature interfacial shear and tensile strength are ≥ 150MPa and ≥ 70MPa, respectively. Any joined material that meets these strength metrics must also survive thermal shock testing, material remains joined with minimal to no damage of either material or the joint, in order to be considered a success.

PHASE II: Utilizing the successful fabrication techniques developed in Phase I the Phase II effort will have two primary tasks. One will be focused on the optimizing the joining procedure to achieve higher interfacial properties as well as increased oxidation and thermal shock resistance plus expansion of the material selection for the UHTC (inclusion of Hf-based compositions and/or high entropy alloys) and if appropriate the substrate material. The other objective will be the development and testing of procedures and methodologies to fabricate near-net shape and net shape components with complex geometries, such as leading edges and curved surfaces, needed for hypersonic flight.

The characterization tasks from Phase 1 will be repeated on any joined materials fabricated with an optimized joining techniques or any newly developed material combinations with the following changes:

- Characterization of the UHTC/substrate joints to determine interfacial mechanical properties such as shear and tensile strength from room temperature to 2000C,
- Oxidation resistance of the joined UHTC/substrate material will be determined from room temperature to 2000C, and
- Thermal shock resistance of the joined UHTC/substrate material will be determined by heating the joined material to 2000C followed by a rapid quench to room temperature.

Additional testing and evaluation will include:

- Conduct burner rig tests at temperatures up to 2000C in an oxidizing environment to determine the performance and lifetime of the joined material,

- Determine the performance of the joined material at high G shock loads (up to 25000G), and
- Determine the performance of near-net and net shape components with appropriate complex geometries by exposing them to the harsh aerodynamic environments experienced during hypersonic flight.

Success will be determined if the joined material system with a complex geometry has an interfacial shear and tensile strength of ≥ 150MPa and ≥ 70MPa, respectively at 2000C, survive thermal shock testing with the material system remaining intact with minimal to no damage of either material or the joint.

PHASE III DUAL USE APPLICATIONS: It is envisioned that the R&D conducted as part of this STTR will provide the foundation of a commercially available method for joining the dissimilar materials needed for military weapons systems to survive and provide maximum performance in the extreme environments experienced in hypersonic flight. Of specific interest will be the development of material systems that can handle the environments experienced by a nose cone and other leading edge applications.

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KEYWORDS: Hypersonic Flight; Ultra High Temperature Ceramics; Joining; Bonding; Thermomechanical Properties

VERSION 3

A23B-T006 TITLE: Modeling Tools for Hypersonic Flight

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): 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 section 3.5 of 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 time-accurate aerothermodynamics of hypersonic vehicles.

DESCRIPTION: 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 CREATETM -AV Kestrel team has been developing a comprehensive suite of codes with a combined on-body/off-body computational approach for the prediction of flows around such vehicles for over a decade. The Army has unique gaps in understanding the flight characteristics (e.g., flow structures, pressure distribution, thermal loading) of hypersonic vehicles at high Reynolds numbers, in small physical scales with geometrical uncertainty, and with configurational asymmetries. While robustness and accuracy of Kestrel computational fluid dynamic (CFD) solvers is under continuous improvement [2,4,5], recent advancements in hypersonic boundary layer transition and turbulence modeling [6] for on-body solvers and sub-filter-scale (SFS) vorticity-preserving methods for off-body solvers [3] are yet to be incorporated into Kestrel. 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 Army hypersonic vehicle's performance.

For the near-body analysis, several mesh options are available in Kestrel including strand, structured, and unstructured meshes. The off-body dynamics of freely evolving vortical wakes are handled in Kestrel via a high-order block-Cartesian Adaptive Mesh Refinement (AMR) approach. In both the on-body and off-body domains, numerical dissipation decreases the effective resolution and overall fidelity of computations, in exchange for high degrees of robustness, especially with complex vehicle geometries [2,4].

The fidelity of the Kestrel suite needs to be augmented specifically to capture key features of hypersonic flight, namely: (a) boundary layer transition locations and hypersonic turbulent heat-fluxes and shear-stresses (on-body); (b) high-Reynolds-number high-speed vortex dynamics in the wake (off-body). More specifically:

(a) In the near-body region, key fluid dynamic features to capture include ultrasonic acoustic waves trapped in the boundary layer responsible for hypersonic boundary layer transition to turbulence under canonical flow conditions. To improve Kestrel's hypersonic transition modeling capabilities, verification and validation against high-fidelity numerical approaches capable of shock capturing and dynamic turbulence modeling [6], and experimental data from hypersonic quiet wind tunnels [1], respectively, are required.

(b) In the off-body region, compressible coherent vortex structures, and their interactions with shocks, affect aerodynamic forces and moments of projectiles and lifting bodies. Kestrel's off-body solver currently lacks adequate SFS -- or large-eddy-simulation (LES) -- closures for high-Reynolds-number compressible vorticity. Classic LES models rely on a local isotropic turbulent eddy viscosity closure for the SFS stresses; however, such approach is overly dissipative [4] if not equipped with a dynamic procedure [3].

This should leverage any related investments from partners such as the Air Force or NASA. This applies broadly to the energy category of efficiency because the utilization of hypersonic weapons may reduce the timeline of conflicts which ultimately reduces energy.

PHASE I: The Phase 1 effort shall carefully assess the current hypersonic flow prediction capabilities of modern multi-physics solvers (e.g., Kestrel) [5] against benchmark-quality hypersonic quiet wind tunnel experiments [1] and state-of-the-art high-fidelity calculations [3,6] for flow conditions and geometries of interest to the Army. An uncertainty analysis of the predicted boundary layer transition location, and the on-body and off-body turbulent shear-stress and heat- flux levels, should also be carried out by exploring the currently available multi-physics solvers (e.g., Kestrel) model parameter space. Focus of the work will be with unstructured, finite-volume solver, KCFD, for near- and off-body predictions and the high-order, finite-volume Cartesian solver, e.g., SAMAIR, for off-body only predictions. However, methods developed will be applicable to other modern CFD solvers (e.g., Kestrel).

Wind tunnel data should replicate natural transition dynamics under quiet conditions over the full extent of an Army reference vehicle, including on-body pressure sensor data and off-body wake surveys, for canonical flow conditions (e.g. low enthalpy and zero angle of attack). Reference boundary-layer-attached high-fidelity simulations need to capture the full range of boundary layer dynamics, from the modal transition process to the turbulent breakdown including the intermittency of the transitional region.
One of the Phase 1 outcomes will be outline of Phase 2 schedule for implementation of augmented hypersonic transition and turbulence models in Kestrel, developed in coordination with the CREATE^TM-AV team.

PHASE II: Phase 2 should involve direct modifications to the on-body and off-body source codes of the Kestrel solvers (or utilization of the external Python-API) executed under close supervision by the CREATE^TM-AV team. Once new functionalities are integrated and tested, re-assessment of Kestrel's performance on the Phase 1 canonical benchmark cases should be completed to highlight and quantify improvements made. After re- assessment, the new implementation should be tested against larger-scale and more complex hypersonic test cases, which may include non-zero angles of attack and aerothermochemistry effects.

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: Hypersonics, aerothermodynamics, modeling, design, tools, air vehicles

A23B-T007 TITLE: Precision Control of High-speed Autonomous Vehicles under High Disturbances

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy, Integrated Network System of Systems

OBJECTIVE: This project seeks the development and demonstration of algorithms that support near-optimal control of autonomous high speed aerial vehicles in real time, with precision, and in challenging and adversarial environments.

DESCRIPTION: Unmanned Aerial Systems (UAS) used by the Army may be subject to harsh conditions in hostile environments. They need to be able to sense heavy disturbances in their environment that affect their operations, instantaneously adjust to overcome their impact. Furthermore, they should form and track a mission supporting trajectory in real time with speed and agility.

Control systems that directly integrate feedback from complex inertial sensors, such as high-end inertial measurement units, or novel odometry systems, and semantic feedback from exteroceptive sensors, such as cameras have the potential to substantially increase the maneuvering capability of high-speed vehicles used or envisioned by the Army. Such measurements can be used in the feedback loop to instantaneously adjust controls to overcome disturbances, as well as predicting abrupt changes in the disturbances and issue predictive control mechanisms. This approach could enable safe and effective operation of for small UASs under excessive wind, abrupt changes in atmospheric pressure due to effects such as blast waves, and occurrence of obstacles which may not be known in advance. This project seeks the development and demonstration of algorithms that can control autonomous aerial vehicles with precision in challenging and adversarial environments listed above, using integrated real-time information from precision inertial sensors and high-frame-rate cameras. The trajectories are pre-determined by the mission in terms of a sequence of waypoints, but they can be subject to small changes based on real-time information acquired by sensors. In general, models describing such systems are complex, and real-time generation of time optimal control policies is challenging. Incorporation of data driven approaches using innovative machine learning algorithms could provide acceptable near-optimal solutions. The research also involves integration of information from a variety of sensors into a from that can be used by the controllers to ensure the stated goals. The proposed algorithms should be implementable over computing hardware that can fit the platform of choice for the demonstration. Sensors that can provide the required information should be specified and the impact of possible gaps in their commercial availability should be identified. It is expected that the computed control laws can provide a performance within 20% of is preselected values of the trajectories and the instantaneous velocities as obtained from simulations and analysis. The demonstration should produce tracking errors no larger than 20 centimeters over the planned trajectory with wind conditions less than 20 miles/hour and have the errors stay bounded under more challenging conditions. A UAS of four vehicles should be able to perform agile movements as required by the control law at a speed more than 15 miles/hour, while reaching the maximum speed of the platform in favorable parts of the trajectory.

PHASE I: During Phase I effort, the proposed control algorithms will be completely specified and validated using simulations over realistic scenarios. The theoretical underpinnings of the proposed algorithms should be discussed with technical rigor, accompanied with their analysis of stability, safety and convergence conditions.

PHASE II: Four or more or small-scale prototype vehicles with sensor, computation and control units will be designed based on the numerical model and design methodology developed in Phase I, technologies. The prototype devices can be built on commercially available state of the art small rotary wing quadcopters. If applicable, performers are encouraged their own designed crafts with comparable or better performance than commercially available units. Technical risks will be identified and plans for minimizing these risks will be devised.

PHASE III DUAL USE APPLICATIONS: Phase III effort will explore opportunities for integrating developed technologies into various UAS and weapon systems used by the Army.

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KEYWORDS: UAS, Trajectory Planning, Time Optimal Control, Reinforcement Learning

VERSION 3

A23B-T008 TITLE: Bright Blue Semiconductor Laser Arrays for Military Applications

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Integrated Network System of Systems, Directed Energy

OBJECTIVE: Develop compact chip-scale blue laser systems with high beam quality useful for machining and propagation. Advances based upon the coherent beam combining of diode lasers of high brightness are sought.

DESCRIPTION: Laser systems in the infrared have a long history of development for both DoD and commercial applications. Blue laser diode systems have been developed with improved performance over the past 2 decades; however, their brightness and power levels are much less than the best infrared systems. Of particular interest is GaN based blue laser diodes which have superior brightness and power scaling potential over the current state-of-the-art. Blue light at wavelengths around 450 nm is of particular interest due to the increased absorption in many materials, particularly metals. The laser energy can thus be transmitted into the material more quickly for more precise machining with less power. The Army would like to develop superior blue laser systems to assess applications in machining and directed energy where more compact and high performing systems may be possible. Diode systems are of interest due to their compact size and GaN is known as a high thermal conductivity material so may be amenable to significant power scaling if coherent combining architectures can be developed. Finally, high beam quality and brightness are of interest for the applications and may require consideration of the laser diode architecture itself, and not just the beam combining architecture. However, the desired metrics for this topic allow for flexibility in the device approach.

PHASE I: Pursue chip-scale directed energy beam combining techniques using high efficiency diode lasers exceeding 30% wall-plug efficiency each with 0.4-0.46 micron wavelengths. Design coherent beam combining architecture for either surface emitting arrays or in-plane laser beam combining. Use of monolithic cavities or chip-scale solutions should be pursued both to demonstrate minimal footprint and show a path toward combining larger numbers of lasers. Additional design considerations should be investigated for the incorporation of effective liquid cooling of arrays to explore maximum power levels. Brightness levels of 200 MW/cm2*sr should be shown to be feasible along with power scaling to > 100 W power levels/cm2 – without coherent combining, but to show thermal heat dissipation design considerations. A demonstration of high-brightness, single mode, Watt-level single emitters should be made along with designs for coherent combining of arrays to reach at least 15 W.

PHASE II: Continue implementation of coherent beam combining designs. Pursue 15 - 100 W peak power, uncooled coherently combined arrays and designs for higher power, cooled arrays. Brightness levels of 1000 MW/ cm2*sr should be demonstrated that achieve combining efficiencies of 70% or more for the chip-scale architecture.
Optimization of the arrays and studies on minimal spacing between individual lasers for the nominal power target level and within the beam combining architecture should continue along with needed studies to explore power scaling with larger arrays. Demonstration of chip-scale DE systems that achieve > 15 W peak power with designs that can scale to over 100 W and potential to achieve kWs. An assessment of cooling for the array to achieve continuous wave operation should be made toward phase III demonstrations. Eventually, cooled arrays of 100 W or more per square centimeter average power are desired.

PHASE III DUAL USE APPLICATIONS: Pursue further optimization of array cooling and power scaling with refined chip-scale designs. In addition, multi-stage architectures should be pursued to combine lower power arrays to achieve kW power level output. Monolithic cavities should be pursued for at least the first stage of combining with secondary combining by either external cavities or secondary monolithic cavities. Other consideration to utilize techniques to create lower power arrays (still multi-Watt) for additive manufacturing, under-water laser communications, and beam scanning and surveillance lidar should be made. Particular consideration for phased arrays should be considered for beam steering and adaptive optical beam control to mitigate atmospheric turbulence to achieve maximum power on target.

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KEYWORDS: blue laser diodes, additive manufacturing, brightness, gallium nitride, directed energy, coherent beam combining

A23B-T009 TITLE: Small Unmanned Aerial System for Surveying the Electromagnetic Spectrum

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

OBJECTIVE: Develop a UAS mountable sensor and transmit package that will provide a standalone low-cost survey, including geolocation, of the electromagnetic spectrum without the need for corporate support.

DESCRIPTION: Many military and civilian applications require rapid survey of the electromagnetic spectrum for identification and the geolocation of electromagnetic emitters. A UAS provides an ideal platform for rapid surveys in possibly hazardous environments. For example, in a natural disaster Emergency Management Services (EMS) require a rapid means of surveying the electromagnetic spectrum that will identify cell phone signals and locate the sources of those signals. The small tactical military unit has a similar need. The technical challenges are developing a low weight sensor that will detect signals, provide geolocation from a small platform, and in real time relay the geolocation information back to decision makers. In the operational scenarios envisioned there cannot be the expectation of external technical support that would aid in the identification and classification of signals. In addition, the form factor of the UAS should be one that enables a single person to carry and deploy, e.g. a quadcopter drone.

With the recent development of lightweight, high fidelity RF components through advanced manufacturing techniques and advanced genetic algorithm design provide a new technology to enable the precision, range and SWAP needed for electromagnetic spectrum surveying in battlefield environments. As an example, application specific electrically small antennas can be manufactured with minimal time, cost and weight. In addition, RF shielding for high-dynamic range measurements can be enabled through light-weight artificial materials acting as shields and directors, separating the electrically noisy components of a UAS from sensitive RF electronics.

Traditionally, communication signals have been identified through correlation of integrated emissions over a period of time. Civilian and military communications have evolved so that the frequencies use short duration pulsed communications and each emission at subsequent intervals can be centered at different frequencies. Technology is required to efficiently capture the presence of signals rather than the content of the actual signals. Thus, it is more important to know that there is a signal and locate the source of the signal than to know details about the signal. Details such as operating frequency and modulation characteristics are not as important but would of course be of interest. Geolocation is also important and possible solutions include using multiple UAS platforms, using synthetic aperture techniques, time of arrival, or possibly even signal strength determinations as the UAS flies in a formation.

This topic shall be manufactured and/or assembled within the continental United States.

PHASE I: Develop a system design for a Class I or Class II UAS platform or platforms to map electromagnetic signal emitters including signal type and geolocation. The system should meet threshold values of a payload capacity of up to 10lbs and a minimum operational time of 15 minutes with a minimum observational range of 1 km and an objective payload weight of 5 lbs, operation time of 30 minutes, and observational range of 5km. This should include a spectrum sensing algorithm for use on a UAS and a corresponding system hardware architecture. The objective for spectral sensing should be between 3MHz-6 GHz, able to sense RF power below -90 dBm and produce an accuracy of < 100 meter of signal emitter location.

PHASE II: Design and fabricate a UAS electromagnetic sensing system including the algorithms developed in Phase I. The system sensitivity will be improved to below -100dBm. The design of RF shielding and directionality for signal enhancement through custom antenna design and shielding will be demonstrated. The system should then be integrated with a UAS platform that meets or exceeds PHI standards with an improved flight time of no less than 30 minutes and range > 10km supporting maximum payload. Data can be stored locally for retrieval upon return, however the ability to transmit data concurrently with spectrum and location mapping is desired. The UAS should be launchable from a single person. The sensing system should be able to: identify signal emitters by frequency and power, sense RF power below -100 dBm, and provide geolocation with <25m resolution.

PHASE III DUAL USE APPLICATIONS: The UAS platform demonstrated in Phase II will be developed for specific mission targets in collaboration with Army needs. It is expected that the payload capacity should increase to >15lbs, range should be increased to > 50 km with a flight time > 60 minutes and multiple sensing frequency bands can be concurrently sensed. The UAS system should be able to sense RF power below -100 dBm and also geolocate with < 10 m resolution.

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KEYWORDS: UAS, UAV, electromagnetic spectrum, sensing, geolocation

VERSION 3

A23B-T010 TITLE: Uncertainty and Model Predictive Control During Discontinuous Events in Autonomous Legged Robots

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy, Integrated Network System of Systems

OBJECTIVE: An autonomous legged robotic control system capable of navigating highly uneven, obstructed, and uncertain terrain.

DESCRIPTION: The future Warfighter will require autonomous robotic systems to traverse highly uneven, obstructed, and uncertain terrain at speed. Legged platforms are clear frontrunners to meet this requirement, but the control of such systems presents a substantial engineering challenge. However, recent developments in hybrid dynamical systems (the branch of control engineering science that effectively models legged systems) and computational capability suggest that the time to address this challenge has arrived. New techniques in signal filtration and uncertainty characterization may be refined to create a controller capable of guiding a robotic platform across terrain that, up until now, has been impassable by an autonomous agent. Successful performers will have to prove the validity of novel physics-based models and control frameworks for a quadruped robot in question for wide arrays of tasks and demonstrate superiority of this paradigm over learning-based control in specific situations. The results will be further streamlined and tested on current quadruped robots.

PHASE I: Design, develop, and validate improved techniques for state estimation and uncertainty propagation in model predictive control of hybrid dynamical systems - specifically quadruped robots in dynamic and uncertain environments. Demonstrate proof-of-concept of this new control paradigm, and quantify its efficacy over the current state-of-the-art. This demonstration should illustrate the ability of a quadruped robot to successfully autonomously navigate a test environment featuring sharply uneven terrain (roots and rocks whose characteristic length are on the order of, and slightly larger than, that of the quadruped foot) hidden underneath grass or grass-like obstructions whose height is on the order of the robot's. A successful demonstration will permit a quadruped to traverse ten body lengths at 0.5 body lengths per second over flat but uneven terrain featuring ground level variance and grass-like obstructions not exceeding 20% of the robot's height.

PHASE II: Design, develop, and validate broad techniques for state estimation and uncertainty propagation across a wide array of physical environments in which a quadruped robot may operate. Demonstrate integration with existing novel perception and sensing capability in a path-planning exercise whose terrain includes obstructions like those in the demonstration of Phase I. Phase II should extend the methodologies of proprioception developed in Phase I to enable increased performance. Compare the efficacy of this new controller against that of traditional techniques such as deep reinforcement learning (DRL) controllers or Model Predictive Control (MPC). A successful demonstration will permit a quadruped to traverse a five body-length incline of +/- 20 degrees with root-like obstructions and slippery surfaces at 0.3 body lengths per second.

PHASE III DUAL USE APPLICATIONS: The end-state control architecture should be mature enough to extrapolate locomotor performance to any number of scenarios, environments, and robotic platforms. The ideal resulting controllers will feature selective frameworks (such as a framework that could choose between MPC, DRL, etc.), and the inherent ability to determine what control technique is most effective for the task at hand. Production-ready controllers will also enable a robotic platform to extract itself from a ”stuck” position in brush, soft soil, and/or rocky terrain.

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KEYWORDS: Robotics, Control, Dynamical Systems, Hybrid Dynamical Systems, Model Predictive Control, Perception, Proprioception, Exteroception, Path Planning, Nonlinear Systems

VERSION 3

A23B-T011 TITLE: Development of pyrolysis optimization methodology for carbon/carbon materials

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): 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 section 3.5 of 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 methodology for design and optimization of pyrolysis schedules to generate desirable carbon matrices for carbon-carbon composites.

DESCRIPTION: Carbon-carbon composites (CCCs) have been utilized for hypersonics applications for decades. For much of that time, the state of the art in source materials, particularly for the matrix phase, has advanced slowly or not at all. Recently, however, a spate of new potential materials (particularly polymer resins) have been developed and are being evaluated as possible precursors for CCCs. The development and commercialization of these polymers represents an exciting opportunity to meaningfully advance the state of the art in CCC fabrication. However, to date, the manufacture of CCCs is still a long and expensive process, and the urgent and increasing DoD need for these materials in the short and medium term necessitates efforts to bring article lead times and cost down. Since CCC costs are primarily driven not by precursor material costs, but by processing costs, it is important to assess new potential precursor material solutions by the impact of their use on the efficiency of downstream processing steps, i.e., densification cycles.

However, the efficacy of a given potential material solution is driven not only by the chemistry of the matrix precursor material, but by how that chemistry behaves during the pyrolysis cycle to which the material is subjected to render a carbon matrix [1]. The nature of the pyrolysis cycle determines several important factors of the resulting matrix and composite. First, the details of the pyrolysis cycle can affect the resulting char yield [2], which is a metric that receives a large amount of attention from polymer developers as they develop new materials. Second, the differences in pyrolysis cycle can influence the microstructure of the resulting voids left behind after pyrolysis [3], which can be large drivers of the efficiency of subsequent densification cycles. That is, for the purposes of redensification, it is desirable to have voids which are 1) of a size which can be efficiently filled by the carbon medium used downstream, and 2) highly connected throughout the part rather than closed and isolated. Third, the pyrolysis cycle parameters should allow for volatiles generated during the pyrolysis to leave the material quickly enough to avoid generating excessive pore pressures [4], which can lead to undesirable outcomes including destructive delaminations, which may render a CCC part unusable.

Currently, there are no commercially available methods to guide resin development or to optimize the pyrolysis of new resins with an aim to improving any of the above metrics. Therefore, we seek the development of novel tools and approaches to optimization of pyrolysis cycles that will allow for more cost effective and efficient densification of CCCs for hypersonics applications. Such tools should be robust and broadly applicable to different chemistries of interest, rather than tailored exclusively to one particular chemistry, and be transitionable to DoD and industry partners.

PHASE I: The offeror shall develop a method to optimize the pyrolysis cycle for one carbon precursor (e.g., resin or pitch) material of interest to the DoD hypersonics community. This method shall be demonstrated to achieve meaningful improvement of some aspect of the resulting carbon matrix in a CCC that is expected to result in materially improved efficiency of downstream densification cycles.

Measured improvement will be in the context of a composite form relevant to DoD hypersonics needs, i.e., either a continuous fiber 2D or 3D woven carbon form of at least ½” thickness. Metrics of improvement may include 1) increase in char yield, wherein the offeror will show at least 10% improvement in char yield over the baseline case; 2) improved void microstructure for efficient redensification, wherein the improvement may be compared to the baseline case using void characterization techniques including, but not limited to, mercury intrusion porisimetry, pycnometry, computed tomography, or diffusivity measurement; or 3) any other reasonable metric commonly accepted by the CCC community as an indicator of expected improvement in densification efficiency. The baseline in all cases will be defined as a temperature ramp from room temperature to 1000°C at a rate of 5°C/min in an inert atmosphere, or some other reasonable pyrolysis cycle in common use in the industry. The offeror may make use of industry- and DoD-derived databases of pyrolysis processes if these are available, but as these will largely be proprietary, the offeror may need to conduct pyrolysis cycles independently to establish the necessary datasets for development of the tool.

The offeror is encouraged to keep in mind the need to deliver a product that can be readily transitioned and commercialized at the end of the period of performance.

PHASE II: The offeror shall expand the method developed in Phase I to demonstrate the broad applicability of the method to at least two additional carbon matrix precursor chemistries of interest to the DoD hypersonics community. The offeror will demonstrate improvement of pyrolysis cycle for downstream reinfusion/densification with, e.g., demonstration of more complete and uniform infusion of polymer resin into pyrolyzed composite compared to baseline. (Additional pyrolysis and reinfusions beyond this are not required.)
The offeror shall deliver a method and toolset that can be readily transitioned and commercialized. The toolset may be standalone software, software modules that can be integrated into existing commercial software, an analytical model, or any other similar transitionable knowledge product.

PHASE III DUAL USE APPLICATIONS: The offeror is expected to aggressively pursue opportunities to market the method developed herein for use in CCC fabrication for DoD-relevant hypersonics applications.

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KEYWORDS: Carbon-carbon; pyrolysis; optimization; polymer design; hypersonics; materials; processing.

VERSION 3

A23B-T012 TITLE: Environmentally Stable Perovskite Solar Cell Module

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

OBJECTIVE: Design and demonstrate a combined materials-, device-, and module-based engineering approach to creating environmentally stable perovskite solar cell modules.

DESCRIPTION: Perovskite solar cells (PSCs) are an increasingly promising photovoltaic (PV) technology, as their power conversion efficiency has increased from less than 4% at the outset of research in 2009 to over 25% today [1 – 4]. Metal halide and hybrid perovskites adopt the general ABX3 chemical formula and crystallize in the perovskite structure, where the A-site is typically occupied by an organic cation like methylammonium or an alkali ion like Cs, the B-site is occupied by a metal cation like Pb, and the X-site is occupied by a halide ion like Cl. This class of perovskites exhibits strong light absorption and emission, has excellent electronic transport characteristics, and is amenable to solution-processing methods. These advantages may translate to significant improvements in PV size, weight, power, and cost (SWaP-C), which could enable the US Army to efficiently generate electrical power from the sun in a variety of environments ranging from large permanent installations to Soldier-level power-on-the-move. Despite these advantages, poor thermodynamic stability, hygroscopic behavior, and poor environmental stability continually plagues PSCs and is limiting their development and ultimate technological impact. This challenge is manifold: lead halide perovskites themselves are thermodynamically unstable with respect to decomposition (i.e., they have a positive enthalpy of formation) [5]; high mobility of X-ions causes significant ion migration during PSC operation and degrades material quality and PV performance; thermal stresses and thermal cycling during operation further degrade performance; and the presence of humidity during PV operation ultimately destroys crystal quality and PV module performance over long periods. These problems are compounded by a lack of mechanistic understanding of degradation modes.

Thus, a holistic research effort is needed to improve stability across the PSC hierarchy, ranging from fundamental science and engineering at the materials level, to device engineering, to module design and integration. This scope-encompassing effort would provide (a) better insight into the physics and chemistry of perovskite degradation; (b) new materials design rules that imbue perovskites with resistance to thermodynamic instability and ion migration; (c) device engineering approaches spanning contacts/electron transport layer/hole transport layer/substrate that address interfacial, thermal, and moisture instability; and (d) module engineering approaches that mitigate or eliminate sources of instability (e.g., moisture, thermal regulation) that cannot otherwise be addressed with materials design or device engineering approaches. Recent isolated, limited-scope research advances suggest this approach is feasible—for example, perovskite A- and B-site ion composition can be tuned to improve stability at the materials and device level [6]. Likewise, composition and tolerance factor engineering in oxide [7] and hybrid perovskites [8] suggests that entropy may be an underutilized tool for thermodynamic stability, i.e., an “entropy-stabilized” hybrid perovskite [9,10]. Interfacial ion-blocking barriers in devices may be useful to modulate chemical potential to suppress ion migration [11]. Ionic passivation of grain boundaries may also suppress ion migration [12]. Encapsulation strategies at the device and module level can provide added protection against humidity and thermal cycling, though more work is needed [13].

PHASE I: Design a concept for an environmentally stable perovskite solar cell module that incorporates stability science and engineering at the materials and thermodynamic stability level, device level, and the module/packaging level. Describe the proposed thermodynamics and materials design science, device engineering, and module packaging schemes that will be employed. Perform ab initio atomistic modeling, molecular dynamics simulations, thermodynamic calculations, electromagnetic simulations, finite element analysis, and/or technology computer-aided design (TCAD) as needed to demonstrate the feasibility of the proposed approach. The module design must have a minimum of 400-square-cm PV-active area and consist of four (4) individual 100-square-cm perovskite solar cells wired in series, parallel, or combination thereof.

The module must be designed to have an absolute power conversion efficiency of 15% or greater. The module must be designed to retain 90% or more of its initial power conversion efficiency over an 8000-hour period while being subjected to 1 Sun, 40˚C, and 85% relative humidity (RH) for at least 4000 hours. Outline the techniques and procedures that will be used to fabricate the proposed design and characterize its PV power conversion performance. Outline the necessary techniques and procedures specifically needed to evaluate PSC environmental stability based on, or appropriately adapted from, the International Summit on Organic PV Stability (ISOS) [14]. Proposed stability tests must include, but are not limited to, shelf-life and dark-storage testing, outdoor testing, light-soaking testing, thermal cycling testing, and combined light-humidity-thermal cycling testing. The proposed model solution must elucidate the stability parameters requirements, stability constraints, and demonstrably meet the elements critical to success of the proposed design.

A critical Phase I deliverable is to create at least one physical module prototype that successfully demonstrates one or more of the stabilized solutions that are critical to success of the proposed model design. This prototype must demonstrate one or more of the proposed stabilization approaches: improved perovskite materials thermodynamic stability, device engineering, and/or the module integration scheme. This physical module prototype must have at least 100-square-cm PV-active area and a power conversion efficiency of 7.5% or greater. The prototype must retain 75% or more of its initial power conversion efficiency over a 720-hour period while being subjected to 1 Sun, 40˚C, and 85% relative humidity (RH) for at least 360 hours.

PHASE II: Based on the designs, modeling, and prototypes from Phase I, fabricate, test, and demonstrate at least one operational PSC-based solar cell module. The module must have a minimum of 400-square-cm PV-active area and consist of four (4) individual 100-square-cm perovskite solar cells wired in series, parallel, or combination thereof. The module must have a power conversion efficiency of 15% or greater. Perform the proposed ISOS testing protocols and any additional tests, as appropriate, to characterize the solar module stability. Using accelerated and/or surrogate testing methods, environmental chambers, and/or field testing, demonstrate that the prototype module will retain 90% or greater of its initial power conversion efficiency over 8000 hours when subjected to 1 Sun illumination and the entire range of climactic operating conditions (i.e., 11 different daily cycles in air temperature and relative humidity) defined in Table 3-1 of AR 70-38 [15]. Data and metrics to report must include initial solar cell characterization (current-voltage curve, maximum power point, internal and external quantum efficiency), encapsulation strategy and performance (wiring, layering, edge sealing, geometry, evolution of stresses/strains within these components), aging conditions (electrical bias, cycling, light, temperature, atmosphere), number of samples, outdoor stability, and, importantly, the evolution of power conversion efficiency over time (i.e., how long until the module efficiency degrades to 90% of its maximum power output or peak efficiency?).

PHASE III DUAL USE APPLICATIONS: Phase III will transition the newly developed stabilized PSC module technology to commercial availability through prime contractors that build integrated solar power systems, the original equipment manufacturers that manufacture PV modules, other relevant suppliers, and/or other partnering agreement(s), as appropriate. Commercialization of this technology may occur via the incorporation of one or more stabilization approaches anywhere in the PV module (e.g., materials design, device engineering, module integration, etc.).

Ideally, a successful effort will deliver a capability upgrade for a relevant Army Program of Record at the end of Phase III, in the form of a solar power generating system capable of providing power against SWaP-C metrics of $3/W or less, 150 W/kg or more, and a functional lifetime of 5 years or greater. Expected dual-use applications include commercial PV power plants, self-charging electric vehicles, microgrids for self-powering infrastructure components, residential solar power, and portable solar power generators and battery chargers.

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KEYWORDS: Photovoltaics, solar cells, environmental stability, perovskite solar cells, materials, module engineering

A23B-T013 TITLE: Method of Developing Helicopter Source Noise Models using Parameter Identification Techniques

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

OBJECTIVE: Develop a semiempirical tool for generating time-domain based, nondimensionally scaled, acoustic spheres from limited flight test data.

DESCRIPTION: Accurate helicopter source noise models are required by the US Army in order to estimate the acoustic impact of proposed helicopter operations. Conventional helicopter source noise models used by current mission planning tools are empirical in nature, relying on measurements of helicopter noise captured by ground based microphone arrays during steady flyovers [1-2]. These models are entirely empirical, which limit their capability to estimate the noise produced by the helicopter at operating conditions inside the limited measurement database. Therefore, inaccurate estimates are provided when vehicle operations occur at different altitudes, gross weights, and external store configurations than those measured. These models are further incapable of accurately predicting effects of maneuvering flight conditions that are difficult to measure with a ground-based array.

First-principles helicopter noise prediction models exist, but do not have the validated accuracy sufficient to produce reliable estimates of helicopter noise spheres required by mission planners. This topic proposes the development of a time-domain based hybrid method, where a mid-fidelity helicopter aeroacoustic prediction method is calibrated to measured data using a parameter identification approach. Accuracy comparable to empirical models is assured by calibrating the model to the available data; however, the model can be applied to predict noise at conditions that were not measured because it contains a physical model of the helicopter noise sources.

Prior research has proven the viability of this concept through the development of the Fundamental Rotorcraft Acoustic Modeling from Experiments (FRAME) method of developing source noise models for helicopters and other rotorcraft [3]. The FRAME technique has been used to make accurate helicopter noise predictions from limited sets of vehicle data; for example, validated predictions have been made at different airspeeds, descent rates [4], and density-altitudes [5]. Validated predictions have also been made for a variety of horizontal and vertical maneuvers with load factors ranging from 0.5 g to 2 g [6]. However, the FRAME software is at a low TRL and is primarily oriented towards community noise prediction. The goal of this proposed topic is to prompt the development of a commercial source noise modeling method that can support acoustic predictions for civilian and military helicopter operations.

PHASE I: The objective of phase I is to create a proof-of-concept semiempirical tool for generating, time-domain based, nondimensional scaled acoustic data for an isolated main rotor using wind tunnel acoustic measurements, or flight test measurements, as the source of model calibration data. Validate the tool by demonstrating that when the tool is calibrated to a subset of the measured data, the tool can accurately predict the time-domain main rotor harmonic noise radiation for rotor operating conditions both inside of (interpolation) and outside of (extrapolation) the range of data used to calibrate the tool. Develop technology transition plan and initial business case analysis

PHASE II: The objective of phase II is to further develop the tool to accurately model the acoustics of helicopters in free flight. Extend the tool to produce rotor harmonic time-domain noise data for both the main and tail rotors. Develop a method to calibrate the tool using ground-based microphone acoustic data collected during the flight testing of helicopters. Validate the tool by demonstrating that when the tool is calibrated to a subset of measured data, accurate rotor harmonic noise predictions can be made for flight conditions both inside of and outside of the range of calibration data. Extend the tool to generate acoustic data spheres suitable for use as input to existing acoustic propagation software used to assess the acoustic impact of helicopter operations. Refine transition plan and business case analysis.

PHASE III DUAL USE APPLICATIONS: The objective of phase III is to further validate and finalize the tool for routine use in Government and commercial applications. Incorporate noise predictions for non-rotor-harmonic noise sources, such as broadband and engine noise. Validate the tool by demonstrating that accurate noise predictions can be made under atmospheric conditions different from those under which the calibration data were collected. Validate the tool by demonstrating that accurate noise predictions can be made under maneuvering flight using only steady flight noise data for calibration. Integrate the tool with a user interface and develop end-user documentation. The resulting tool is applicable to both military and commercial rotorcraft. Key military applications include predicting vehicle acoustic footprints during flight operations. The validated tool will be useful for accurate land use models for both military and civilian community operations.

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KEYWORDS: Rotorcraft, Helicopter, Acoustics, Noise, Modeling

VERSION 3

A23B-T014 TITLE: Improving the Thermal Conductivity (TC) of Enhanced Performance Coolants (EPC) with inorganic additive nanotechnology

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

OBJECTIVE: A compatible Organic Acid Technology (OAT) coolant with a 50% increase the thermal efficiency over traditional coolants that allows for improved performance of Future Vertical Lift, Unmanned, and ground vehicles.

DESCRIPTION: Develop an advanced Nitrate Free Organic Acid Technology (OAT) based coolant with improved thermal efficiency of at least 50% to reduce coolant needed or improve heat rejection/reliability of affected systems. In May of 2022 DEVCOM Ground Vehicle Systems Center released a technical report in support of the Army converting to modern OAT based coolants. Heavy Duty OAT based coolants are very attractive with up to a five (5) year lifespan versus traditional Supplemental Coolant Additives (SCA) based coolant which have annual service requirements. However, this OAT chemistry only improves the thermal efficiency on average of 2% under laboratory conditions. The reference report by DEVCOM and conducted by SWRL showed OAT coolants at a 60/40 mixture with a thermal conductivity average of 0.4046 (W/mk) versus traditional SCA coolants with a thermal conductivity average of 0.3892 (W/mk). If inorganic additive nanotechnology were added to OAT coolants, a thermal conductivity of approximately 0.60 (W/mk) could be realized while maintaining all legacy performance requirements of the fluids. The new coolant (OAT plus inorganic nano additives) must perform across a wide temperature range between -60°C and 60°C ambient and be compatible to all liquid cooled Army platforms. Thermal efficiency increases of 50% would allow armored vehicles with little airflow to operate more efficiently, UAVs with liquid coolant to reduce operating weights and allow the ARMY to have a single, universal coolant for all vehicles for the next generation of warfighter.

PHASE I: Identify and baseline current OAT coolants. Building upon the previous research conducted by DEVCOM, investigate various inorganic additive materials technology to optimize the thermal efficiency by 25-50% on the two final candidates for OAT/EPC coolants. Demonstrate thermal efficiency while having minimal impact on viscosity, foaming, cavitation, corrosion and without precipitation over an extended service life; begin laboratory benchtop testing on materials candidates. Testing to include by not be limited to:

1. Glycol Content (%) via Refractometer
2. ASTM D1287-11 – Standard Test Method for pH of Engine Coolants and Antirusts
3. ASTM D5931-20 – Standard Test Method for Density and Relative Density of Engine Coolant Concentrates and Aqueous Engine Coolants by Digital Density Meter [10]
4. Thermal Conductivity and Specific Heat using C-Therm TCi Thermal Conductivity Analyzer

PHASE II: Refine and optimize the materials selected in Phase I and develop and deliver prototype OAT plus nano additive coolant for additional benchtop ASTM laboratory testing as needed. Begin long term field trials on selected ground and air warfare systems. Request OEM participation where available.

PHASE III DUAL USE APPLICATIONS: Transition technology to the U.S. Army for adoption and use by specific platforms. Continue long term field trials with monitoring teams. Finalize packaging requirements Integrate this technology where current SCA technology is being utilized. Investigate where cooling systems can be made more efficient due to new EPC cooling technologies.

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KEYWORDS: Enhanced Performance Coolants (EPC), Organic Acid Technology (OAT), GVSC's Ground Systems Fluids and Fuels (GSFF), UAS, Future Vertical Lift (FVL), Nanotechnology, Nanofluids, Nanocoolant

VERSION 3

A23B-T015 TITLE: Solid-State Large Aluminum Additive Manufacturing Replacements

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

OBJECTIVE: Additively manufacture (AM) aluminum alloy 7XXX (Al-Zn-Mg-Cu) or equivalent material via solid-state for replacement of forged legacy components with long lead times and logistics tail.

DESCRIPTION: As the need for sustainment of aging US armed forces aircraft continue to rise and will continue to rise with the introduction of Future Vertical Lift (FVL) [1], there is a growing necessity for supplementing the supply chain for long logistic components to maintain fleet readiness. As a disruptor of traditional manufacturing, AM has come into focus as a leading technology to fabricate components, supplementing hard to procure aerospace components [2]. This is possible due to AM systems offering all-in-one turnkey manufacturing solutions, providing benefits in reducing production costs associated with build time and waste material of traditional manufacturing methods [3]. However, for fusion-based AM processes (e.g. selective laser melting and electron-beam melting), certain alloys suffer from poor weldability impeding fabrication via AM [4], and are typically limited to smaller parts that must fit within 1 sqft. sealed environments for processing. One such alloy system is Al-Zn-Mg-Cu (AA7XXX) aluminum alloys, which comprise the majority of the structural materials used in aerospace across the DoD and industry including FVL offers.

It is well established that the AA7XXX family is traditionally considered unweldable, and when subjected to high thermal gradients, hot cracking occurs in the microstructure. Therefore, fusion-based AM, in which high thermal gradients are introduced into the microstructure similar to welding, typically results in hot cracking and material anisotropy when fabricating or repairing AA7XXX. These deleterious defects within the microstructure reduce the mechanical performance of the material, beyond allowable limits for aviation applications. To alleviate the detrimental-effects to the microstructure, AA7XXX powders for fusion AM have been enhanced with additional alloying elements (e.g. Scandium). However, the introduction of these new additives raises concerns on material response when compared to traditional AA7XXX, and how it will respond during typical aerospace service conditions. Thus, there is need for a 1-to-1 replacement of traditionally high strength, low weight forged aerospace materials to preclude the inherent uncertainties with AM aluminum materials.

Nascent solid-state AM techniques have been proven to be capable of depositing traditional materials, like AA7XXX, due to the low thermal requirements to deposit the material. As a result, the microstructure is not thermally stressed to the same degree as fusion-based AM and is not subject to the same negative effects observed when processing with conventional alloys as the input feedstock. Additionally, solid-state techniques are more modular and are not limited to the geometric constraints governed by inert build chambers or laser interactions, permitting significantly larger build areas. However, the low resolution and characterization of the alloys for aerospace components has left technological gaps to permit adoption for aviation applications.

The goal of this topic is to identify a solid-state AM processes that can 3D print traditionally unweldable aerospace materials without adding additional alloying elements to the bulk material for a true 1-to-1 replacement of components. The solid-state AM process will demonstrate the feasibility of printing a large aviation component free from contamination and additional inoculants. Then after successful printing, an optimized process will produce a final aerospace component as a demonstration.

PHASE I: Demonstrate the feasibility of printing a large, full-sized aviation component (build area/volume larger than 1sqft/1ft3) via a friction-based solid-state additive manufacturing method utilizing a high-strength alloy (e.g. 7XXX). This component will serve as both a technology demonstrator and a first article cut up. Initial microstructural and mechanical characterization will be performed by extracting material samples from the first article component to demonstrate a lack of process related defects, porosity, and contaminants, with an initial evaluation of mechanical performance.

Phase I deliverables include a report detailing first article production and evaluation of the sectioned component for process defects and optimization plan for the material and process.

PHASE II: Following the initial successful demonstration using solid-state AM to produce a print with a 7XXX aluminum alloy, process optimization will be conducted to further refine parameters. The optimized parameters will then be used to establish repeatability through analysis of process structure property (PSP) relationships and mechanical testing. Material samples shall be evaluated in the final post-processed condition. Extensive microstructural evaluation utilizing a combination of optical and electron microscopy and X-ray spectroscopy and tomography provides an in-depth analysis of the microstructural evolution to elucidate production and post-processing effects on the final prototypes. This includes inspections on density, phase identification and dispersion, and granular characterization. Additionally, mechanical performance of the optimized component shall be evaluated with tensile and fatigue, with detailed observations on damage mechanisms and failure modes using microscopy. Test and evaluation techniques shall follow ASTM standard procedures to be documented and contrasted against legacy aviation material requirements.

Complete data and manufacturing instructions from process preparation to post-processing shall be delivered in a phase II report along with a second finished component fabricated with the optimized and substantiated material developed under this effort.

PHASE III DUAL USE APPLICATIONS: The civilian and defense sectors would benefit from this developed technology as an alternative means to rapidly produce large scale, long lead wrought aluminum forgings with that match original requirements of the legacy component that would be otherwise difficult to match through current additive manufacturing methods. DoD may pursue this technology for transition into the larger organic industrial base, as a close out report with all data and documentation necessary to fully replicate large parts within the defense industrial base. Successful delivery of manufacturing instructions will be transferable to the Jointless Hull activities in relation to the Next Generation Combat Vehicle (NGCV) in direct collaboration with DEVCOM Ground Vehicle Systems Center. Thus, successful demonstration of solid-state AM producing an aluminum alloy component with 1-to-1 equivalent material will increase Army readiness and reduce logistical timeframe for component procurement across ground and aviation systems.

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KEYWORDS: Additive Manufacturing, Solid-State, Forging, Aluminum, Replacements, Process-Structure-Property

VERSION 3

A23B-T016 TITLE: Lower Temperature Methanol Steam Reforming Catalyst for Fuel Cells

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

OBJECTIVE: Reduce the hottest components temperature through the development of a lower temperature methanol steam reforming catalyst which can be integrated into existing fuel cell systems.

DESCRIPTION: C5ISR Center, in conjunction with industry, have developed wearable Soldier fuel cell systems that can provide on the move light-weight power for systems operations and battery recharge and extend mission duration and reduce Soldier load (carried weight). Current fuel cell systems have been developed based on the Reformed Methanol Fuel Cell Technology. Soldiers have commented that while using fuel cell systems, this capability increases their autonomy in the field. However, heat signature could be a potential issue, and reduction of thermal signature would be beneficial.

Part of this thermal signature reduction will be achieved through a material solution focused on reducing the reformer temperature, which is the hottest part within a reformed methanol fuel cell system [1-2]. Historically, Reformed Methanol Fuel Cells have commonly used copper zinc oxide, which requires reactor temperatures in the range of 300°C [2-4]. However, recently new catalysts have emerged showing that reactor temperatures as low as 150-200°C are possible [4-7]. In these works, the catalyst is in a powdered form. C5ISR Center desires the catalyst to be pelletized.

Reducing the temperature of the hottest component in the fuel cell system (reformer) has significant impacts to the War Fighter, such as potentially reducing the thermal signature and increasing soldier comfort. In addition, by reducing the temperature of the reformer, the system will have quicker startup times. This topic is appropriate for STTR investment due to an applied research solution that can significantly positively impact system development and addresses Soldier feedback. The new catalyst itself can potentially be a near drop in solution. The catalyst itself shall be a pellet or monolith configuration. The catalyst synthesis approach must be scalable to an industrial setting.

The catalyst will be evaluated and characterized at C5ISR Center. If successful, the catalyst will be incorporated into existing fuel cell systems for further evaluation.

PHASE I: Conduct an initial study and provide potential solutions. Provide initial samples of catalyst for evaluation.

PHASE II: Develop and deliver a new low temperature catalyst with small diameter pellets that are less than 4mm in diameter or supported on a monolith surface. The catalyst should be capable of processing about ml per min of methanol water. Four sets of catalyst will be delivered. Catalyst should operate at near atmospheric conditions while maintaining full conversion 99%+. The new catalyst should be able to operate for >1000hrs, with low level of degradation. As previously demonstrated in literature [4-7] the new catalyst should have an activity of greater than135 µmolH2/gcat-sec at low temperatures, definitive numbers to be provided to firm upon selection. The catalyst should be able to support a minimum GHSV of 6000 -hr determined at reactor conditions. Catalyst will be evaluated multiple metrics.

PHASE III DUAL USE APPLICATIONS: The catalyst developed in Phase 2 will be integrated into the existing fuel cell systems. Update as needed the balance of plant software/firmware for optimal fuel cell system performance. Deliver 5 functioning Fuel cell systems with the new catalyst. A Safety

Assessment Report (SAR) shall be provided with the fuel cells. These systems will be initially evaluated at C5ISR Center for performance characterization, and then evaluated at Soldier touch points for Soldier operational use.

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KEYWORDS: Fuel Cell, Soldier, Reformer, Methanol, Catalysis, Steam Reforming

VERSION 3

A23B-T017 TITLE: Polymer, Solid Electrolyte, and Lithium Anode Battery to Enhance Kinetics

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

OBJECTIVE: Creation of a high energy dense, future safe, lithium-ion battery that facilitates charge transfer of solid-electrolyte interfaces, high voltage cathodes, and lithium-metal anodes.

DESCRIPTION: Higher energy densities can be achieved primarily through pairing high voltage, high-capacity cathodes with Li-metal anodes. To enable the use of next generation elevated voltage cathode materials with lithium-metal anode, stabilizing cathode coatings can be affixed to improve interfacial structural stability, mitigate electrochemical impedance increases, and diminish thermally induced degradation. Additionally, employing electrolytes that can withstand penetration testing without flame and fumes is important for the development of on-platform energy storage such as arial and ground vehicles. Lithium-anodes are vital for improving the energy density of the cell due to the capacity / weight of graphite anodes, although uniform plating and electronic connectivity to the electrolyte needs improvement.

Cathodes with elevated discharge voltages will increase the energy output / electron moved, better understood through this application of the Ohm's Law: Energy Density = (Current Density * Voltage) * Time. Spinel, olivine, and other high voltage cathodes can store high quantities of lithium-ion and discharge at elevated voltages making them prime candidates. Solid-electrolyte batteries are a vital technology that needs to be developed to meet the energy safety requirements for the future Army. They can sustain high cell voltages, which promote greater power and energy capabilities, they are mechanically stronger than liquid electrolyte batteries, fighting dendrite formation with lithium anode increasing safety, and they have high conductivity capabilities leading to high electrochemical performance. The issue with these solid-electrolyte batteries is the elevated charge transfer resistance at both solid-solid interfaces between the electrolyte and the electrodes. If the charge transfer at these interfaces can be improved and the low temperature performance of the solid electrolyte can be augmented. Battery needs to be able to operate in a wide temperature range.

This STTR looks to create artificial solid-electrolyte interface (SEI) layers with conducting polymers to overcome the inherit challenges to ionic transfer across the cathodic and anodic interfaces. These resistances to charge transfer are largely attributed to the poor connection between a solid electrolyte and a solid electrode. Ameliorating these will promote longer cycle lives, improved power, and more stable charge transfer with the lithium-anode, leading to better safety characteristics. Utilizing known supercapacitor work with electrically conducting polymers (ECPs), specifically poly(3,4-ethylenedioxythiophene) (PEDOT), polypyrrole (PPy), polyaniline (PANI), quinone, polyacetylene, and biological derivatives such as lignin / sulfonated lignin, artificial SEI / cathode-electrolyte interface (CEI) layers can exploit the conductive nature of the polymer to assist ionic transport. With these adaptations this battery will fully be able to exploit the inherit safety and energy storage performance of solid electrolyte batteries, while finally amending the internal resistance issues to promote a wide application of energy dense batteries.

This work should be at the STTR level because the maturity of these chemistries is currently in fundamental research.

VERSION 3

PHASE I: Design a concept cell for nonflammable solid-state electrolyte that optimize gravimetric energy density at elevated discharge voltages and prolonged cycle life above 80% capacity retention. Phase I deliverables include monthly progress reports describing all technical challenges, technical risk, and progress against the schedule, a final technical report, and 10 laboratory cells (coin or pouch cells) to the U.S. Army for testing.

PHASE II: Refine and optimize cell level materials selected in phase I and develop and deliver pouch cells to meet target performance requirements of elevated discharge voltage cells, high energy density, decent cycle life capability > 80% capacity retentions at room temperature, and 75% capacity retention at 0 °C with respect to room temperature capacity. Additional optimization with the target of expanding the rate capability of these cells will also be included in phase II. Required phase II deliverables will include 20 cells (pouch), as well as monthly progress reports and a final technical data package.

PHASE III DUAL USE APPLICATIONS: Transition this technology to prototype cells that will be intended for assembly into batteries for soldier carried applications. The deliverable for phase III is multilayered pouch cells with capacities in the order of Ahs to be included in future batteries.

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KEYWORDS: Energy Storage, Polymeric Electrolytes, Spinel Cathodes, High Energy Density, Improved Safety, Soldier Lethality, Future Vertical Lift.

VERSION 3

A23B-T018 TITLE: Highly conductive brominated graphitic fibers for infrared and centimeter-wave electromagnetic attenuation

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 section 3.5 of 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 a high performing infrared and centimeter-wave attenuating graphitic fiber with improved conductivity through heat treatment and bromination.

DESCRIPTION: To maintain operational overmatch of our near-peers, signature management needs to be exploited to the greatest limits of science. Obscuration leverages our resources by protecting multi-million dollar assets with cost-effect aerosol materials. Recent discoveries have illustrated the ability to vastly increase the performance of these obscurants in the infrared and centimeter-wave regions of the electromagnetic spectrum– both areas in which our enemies use imagers to identify our warfighter's locations. This topic focuses on these developments of carbonaceous-based obscurant materials in the form of fibers, either fractal-quasilinear or linear. Due to the recent improved understanding of the significant impact heat treatment and bromination make on conductivity, and thereby efficiency, STTR is the preferred pathway to ensure success among small business and university partnerships (references 5-7). Graphitic particles have long been recognized as obscurants. Such particles can be produced by graphitization of polymers, for example, or from fibrous forms, already nominally graphitic. One cost-effect, scalable approach may be through electrospinning and subsequent heat-treating of these particles. Further bromination of these particles has been illustrated to improve the conductivity above 10^5 mho/cm—a factor that vastly improves obscuration performance. Produced in this way, a low-cost, high performing, high strength material that will not fuse or agglomerate upon compression can be realized.

PHASE I: Demonstrate with 50 milligram or greater quantities, an ability to produce graphitized fibers using high heat treatments in the range of 2800-3000oC on nominal graphite or polymeric material. For IR fibers optical measurements and/or electrical conductivity will be used to determine the success of the heat treatments while for CMW fibers, both optical and electrical measurements (equivalents) will be used. Following successful heat treatments, the graphite fibers should be brominated and additional enhancement of conductivity remeasured for both wavelengths.

PHASE II: Demonstrate that the process is scalable by providing 1 kilogram of samples with no loss in performance from that achieved with the small samples. During Phase II, idealized particle lengths and widths should be achieved for infrared (3-5 µm in lengths, 50-100 nm diameters) and centimeter-wave (one cm or greater in length, 4-10 µm diameters) attenuation. In Phase II, a design of a manufacturing process to commercialize the concept should be developed.

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PHASE III DUAL USE APPLICATIONS: The techniques developed in this program can be integrated into current and future military obscurant applications. Improved grenades and other munitions are needed to reduce the current logistics burden of countermeasures to protect the soldier and associated equipment. This technology could have application in other Department of Defense interest areas including high explosives, fuel/air explosives and decontamination. Improved separation techniques can be beneficial for all powdered materials in the metallurgy, ceramic, pharmaceutical and fuel industries. Industrial applications could include electronics, fuel cells/batteries, furnaces and others.

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KEYWORDS: High conductivity, graphene, infrared obscuration, bromination

VERSION 3

A23B-T019 TITLE: Aerosol Particle Collectors for Microsensor Platforms

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

TECHNOLOGY AREA(S): Sensors, Chem Bio Defense

OBJECTIVE: Develop, demonstrate, validate, and produce aerosol particle collectors which are Size, Weight, and Power + Cost compatible with microsensor platforms and capable of being produced using advanced manufacturing techniques.

DESCRIPTION: Small, low-power, low-cost, networked, and potentially attritable sensors ("microsensors") can be rapidly dispersed over an area to enhance situational awareness and continuously monitor for threats such as toxic chemicals or pathogens. The ability to use networks of smaller and cheaper sensors instead of large and expensive systems will allow Warfighters to maintain increasingly expeditionary postures. Current systems for capturing aerosol particles in defense-relevant size ranges and delivering these particles to downstream devices for analysis are not suitable for use microsensors, due to size, power consumption, robustness, or the ability to operate without manual intervention. Recent innovations in miniaturized components such as pumps, well- or channel-based impactors, electrostatic precipitators, and impingers offer potential means by which to capture aerosols then deliver them in a solvent to a downstream process while remaining small and consuming minimal power. To realize these capabilities, additional development is required to identify specific collection components, match them with air and liquid pumps, and demonstrate the ability to efficiently collect and deliver particles in relevant size ranges. To enable successful integration with multiple types of microsensor detection and identification modules, flexible designs are favored. Desired features include but are not limited to 1) The ability to quickly modify a 'base design' to collect different particle sizes, 2) delivering particles in varying volumes of different solvents, 3) utilization of components designed to be produced close to the point of need using advanced manufacturing techniques, and 4) operating under the control of non-proprietary code to enable agile experimentation and integration with experimental detector and identifier modules.

PHASE I: Identify components suitable to achieve aerosol collection and subsequent delivery in a liquid solvent within a minimal SWaP+C envelope. Demonstrate the function of these components in a breadboard system (it is not necessary to minimize SWaP+C at the breadboard stage, but the ability to make those components work in the tightest envelope possible is a vital criteria for later phases). Evaluate their performance working together in the breadboard system. Deliver a report on the breadboard system to include performance data, cost, size, and power consumption of the breadboard system, and an estimate of the cost, size, and power consumption of the system were it to be integrated, packaged, and optimized. Investigate potential civilian markets for the technology.

PHASE II: Develop an integrated collector module based on the breadboard design: Integrate components into a small physical package (threshold: 350mL, objective: 175mL) with efficient power usage (threshold: can idle for 6 hours and perform 4 collect-dispense cycles on a battery internal to the device, objective: can idle for 24 hours and perform 24 collect-dispense cycles on a battery internal to the device), and reasonable weight (threshold: 500 grams, objective: 200 grams). Demonstrate the performance of this collector module on relevant aerosol challenges. Demonstrate integration with Army-specified detector modules. Participate in a user-engagement event with a field demonstration component. Deliver reports on these activities, prototypes, and technical data packages to include component and system models and software/firmware used on the device. Develop version(s) of the module suitable for identified civilian applications and explore commercialization.

PHASE III DUAL USE APPLICATIONS: Mature concepts and prototypes into a manufacturable or transitionable system: Refine the integrated collector module to improve performance or the ability to flexibly integrate with multiple detectors and multiple missions. Establish the use of advanced manufacturing to adapt the base design to different detectors or missions in collaboration with potential user groups. Develop documentation on the use of the technology for multiple mission types and transition the technology to DoD partners. Commercialize products based on the enabling technologies for civilian applications.

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KEYWORDS: aerosol, particle, collector, sampler, chemical, biological, micro, miniature

A23B-T020 TITLE: Use of Satellite Observations for Analog Ensemble Predictions to Contribute to Decision Advantage

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Integrated Network System of Systems, Trusted AI and Autonomy

OBJECTIVE: Develop an innovative methodology to utilize satellite observations of weather-related atmospheric variables within the analog ensemble (AnEn) technique for environmental predictions, when no in-situ observations (i.e. field data) are available.

DESCRIPTION: Uncertainty in weather prediction affects Army mission preparation and planning degrading decision advantage. Numerical Weather Prediction (NWP) models generate atmospheric forecasts to provide a deterministic weather forecast, but present inherent uncertainty. A number of factors cause uncertainty associated with Numerical Weather Prediction (NWP) models; including but not limited to, errors in initial conditions, quality of the model initialization field, model physics, and various parameterization schemes [1, 2, 3, 4, 5]. Understanding the uncertainty in forecast predictions will address problems in weather support that cause impediments to the Army's mission preparation and planning.

PHASE I: Determine the scientific, technical merit, and feasibility for developing an AnEn framework using satellite observations (potentially also using hybrid in-situ and satellite observations, required in Phase II) for continuous and discontinuous atmospheric variables. Develop a conceptual methodology providing multiple weather and environmental conditions with their associated uncertainty. Deliver a report documenting the research and development efforts along with a detailed description of the proposed final methodology, implementation, and impacts upon uncertainty quantification results.

PHASE II: The methodology will be fully implemented, using the programming language python, enabling straightforward integration with the Army's geospatial software baseline used by geospatial engineers. The code will allow users, whether civilian or Army, to make weather and environmental predictions based on either satellite data or a combination of satellite and in situ observations. A methodology and implementation for hybrid use of satellite and other observational datasets within the AnEn techniques shall be set forth. A report will be delivered that provides an understanding of the AnEn techniques strengths and weakness when utilizing satellite and/or hybrid observational datasets, along with implementation recommendations.

PHASE III DUAL USE APPLICATIONS: The AnEn prediction geospatial tool can be integrated into baseline software on the Geospatial Workstation (GWS) used by Army geospatial engineers, leading to a DoD commercialization potential. The geospatial engineers will benefit from this tool by having the new capability to predict several potential weather and environmental related impacts to mission planning quickly and capture weather-related mission risks caused by prediction uncertainty. Non-DoD commercialization potential exists within the civilian sector. The technology has many potential applications outside of the military to address weather-related forecasting challenges, and topics. For non-DoD sectors, the python based development fosters access and integration opportunities due to the popular adoption of python in many development practices. Furthermore, the ease of integration with geospatial (i.e. ArcGIS) software will facilitate the potential use within the non-DoD sector for those with existing ArcGIS licensure.

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KEYWORDS: uncertainty quantification, data analytics, geoinformatics, analog ensemble, prediction, atmospheric science, machine learning

A23B-T021 TITLE: Ultrawide Transmission Range for Variable Transmission Eyewear (VTE)

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

OBJECTIVE: An active, variable transmission eyewear on a ballistic substrate with ultrawide transmission range that can switch reversibly and automatically between high (≥70%) and low-transmission states.

DESCRIPTION: Soldiers are subjected to quickly changing light conditions, such as inside a dark building versus outside in the sun, within a single mission. The pupil can take a few 10s of seconds to fully acclimate to changing light levels [1]. Additionally, low-energy laser threats such as dazzlers are encountered in the field [2]. Soldiers already have issued (approved) variable transmission eyewear (VTE) on the Authorized Protective Eyewear List (APEL), but the current systems do not provide the required transmission range in a single lens. These are the e-Tint CTRL MS1 Spectacle and the e-Tint CTRL MG1 Goggle. Due to insufficient transmission range, these two designs are currently being fielded with both a variable transmission lens (for use in variable lighting conditions encountered during daytime operations, such as going in and out of buildings) and a standard, high transmittance clear lens for nighttime operations. Based on Soldier feedback during testing, the decision to field a standard clear lens in conjunction with the transition lens was made by eye protection subject matter experts at Product Manager Soldier Protective Equipment. Soldiers commented that the transition lens was too dark for nighttime use [3]. In addition, this creates undue cognitive burden on the Soldier decreasing their situational awareness. In addition, Soldiers may choose to forgo the protection altogether, which puts their eyes at even higher risk. A solution to this problem is active variable transmission eyewear with ultrawide transmission range, i.e., from 10% to 70%, or more, transmission. Previous efforts at active VTE have struggled to achieve much higher than 60% clear state transmission as certain layers have contributed to high parasitic optical losses. VTE with very low transmission in the dark state can also function as laser eye protection for low-energy threats.

The proposed VTE solution should address the following requirements. Variable transmission prototypes must be manufacturable on a ballistic substrate and continue to provide other eyewear functions including anti-fragmentation, anti-scratch, anti-fog, and anti-ballistic. Variable transmission proposals should retain high optical quality. Approaches should be color neutral. While an eyewear is not required in the early Phases, proposals should keep an eye on technologies and approaches amenable to the eyewear platform. Proposals should either have a roadmap to meet or exceed the standard fielded U.S. military combat eye protection requirements, per MIL-PRF-32432. The VTE must reversibly switch repeatedly. It should go to clear state (high transmission) when powered off or fails. Active VTE prototypes should be aware of power needs of proposed solution and work to minimize power requirements. For instance, if a battery is part of a submitted design, then a single charge should last at least 72 hours and be fully borne on the eyewear frame. Ideally switching times should be less than a second, with 250 ms being the objective. Comfort of the VTE should be considered which includes weight, distribution of mass, retention on face, and compatibility with other headgear.

PHASE I: During Phase I, the contractor shall research and develop innovative approaches to ultrawide variable transmission. Proposed solutions should exceed current variable transmission range of 12—65%. Proposed solutions must show how they can achieve higher than 70% clear-state transmission in a single lens. Proposed solutions must be amenable to military relevant eyewear substrates. For the purposes of Phase I, demonstrations may include switchable devices and/or eyewear prototypes that

exhibit active variable transmission. Through Phase I, the contractor should provide monthly progress reports detailing technical and programmatic results.
End products shall include an end-of-phase report with conceptual drawings and a proof-of-concept prototype. End-of-phase report shall include, but not limited to, the following: variable transmission range achieved, power consumption, switching speed, color appearance (i.e., chromaticity), construction of lens and variable transmission layers, electronic schematics, material composition. Ability to enhance situational awareness and increase lethality while preserving existing vision protection capabilities (i.e., be equal to or better than standard fielded U.S. military combat eye protection, per MIL-PRF-32432) should be supported with sound reasoning and substantial evidence.

PHASE II: During Phase II contractor shall address in detail the technical approach and design of the technology chosen in Phase I. Engineering challenges associated with the technological approach should be noted. Minimum required deliverable for the Phase II shall be a switchable active variable transmission eyewear prototype. Dark state transmission should be equal to or less than 15%.

Target clear state transmission is greater than 85%. Prototype shall be on a military relevant substrate. Power shall be on-board prototype. Technical report shall detail optical characteristics (including transmission range and ANSI Z87.1 optical performance), electrical and power characteristics (including power consumed, battery life), and testing associated with MIL-PRF-32432 (i.e., ballistic fragmentation, anti-scratch).

PHASE III DUAL USE APPLICATIONS: The end-state of this technology is for a single combat eye protection for all levels of illumination and provide some protection against laser dazzler threats. Further potential military applications include other headgear platforms that have a need for VTE. Civilian markets for this technology include law enforcement operations, environmental and agricultural markets, and outdoor recreational uses

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KEYWORDS: Eyewear; variable transmission; laser protection; PPE

VERSION 3

A23B-T022 TITLE: Soldier Personnel Protective Equipment from High Energy Lasers

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

OBJECTIVE: A lightweight and wearable Soldier PPE able to neutralize high energy laser threats upon impact and, incidentally, able to alert the wearer of the presence of such threats

DESCRIPTION: High energy laser (HEL) threats are expected to be deployed in the future battlefield. They exhibit many compelling features including speed-of-light engagement, a deep magazine, and limited protection against the highest powers. The threat mechanism is via optical damage and intense thermal damage. These qualities behoove the development of PPE for Soldiers. A solution to this problem does not have to provide complete protection against HELs, even partially protection can buy Soldiers enough time to evade or engage the threats. In addition, the wavelength could be in the near infrared (NIR), such as with a Nd:YAG laser, making it undetectable visually via scattered light. A PPE system was developed for industrial users of high energy lasers [1]. The PPE proposal here could involve a wearable for the Soldier or a shield-like product. HELs can have irradiances greater than 10 W/cm2 or powers greater than 500 W. Even materials with extremely small amounts of absorption in the visible or NIR, such as noble metals, will lead to optical power absorption, heating and thermal runaway as the material gets damaged. Damage leads to further absorption as the material's absorption coefficient increases. Energy can be reflected away and/or spread around to a larger volume to prevent damage.

The HEL PPE must demonstrably reduce the burn injury/damage to both the wearer and the article itself. The wearable must address the following when exposed to a visible or NIR laser of irradiance 100 W/cm2: not allow the laser to penetrate to the skin before 1 minute, result in an inner surface temperature less than 44 °C, i.e., the burn injury threshold, for at least a minute, not catch on fire before either the inner surface temperature is greater than 44 °C or before 1 minute. Proposers should note that HEL PPE that simply reflects all the energy as may cause injury to nearby bystanders. The HEL PPE must be wearable, flexible, able to be carried by an individual Soldier, and greater than 1 m2 in area. ASTM standards for thermal protection should be followed including ASTM 1959, 1930, 1358, and C1055-20 [2—4].

PHASE I: During Phase I the contractor shall research and develop innovative approaches to HEL personal protection. Throughout the Phase I, monthly reports detailing technical and programmatic results shall be delivered. End of products shall include a technical report detailing proposed materiel solution with expected protection levels in terms of inner surface temperature reached after 1 minute of exposure to vis or NIR laser of 100 W/cm2 and expected length of survival against exposure to an HEL. Proposed solution should address wearability, flexibility, weight, and size. Ability to preserve situational awareness and increase lethality of the Soldier should be supported with sound reasoning and substantial evidence.

PHASE II: : During Phase II, the contractor shall address in detail the technical approach and design of the technology chosen in Phase I. Engineering challenges associated with the technological approach should be noted. Minimum required deliverable for the Phase II shall be a wearable HEL PPE prototype of weight per unit volume no greater than 0.465 lbs/ft2, area greater than 10 ft2, and protection level consistent with that described in Phase I. Prototype should also address considerations for coloring (i.e., camouflage), flame suppression, and no drip/no melt. A technical report detailing the construction of the HEL PPE, design choices, relevant physical parameters, including thermal and optical properties, performance against a vis or NIR laser of 100 W/cm2, and engineering challenges of achieving said level of performance.

PHASE III DUAL USE APPLICATIONS: The vision for this R&D is a baseline for HEL PPE for Soldiers and shielding material for equipment such as UASs. The end-state is the ability for Soldiers to have extra time while irradiated to evade or engage. The technology developed here would be transitioned to a Program of Record through the Product Manager (PM-SCIE). Additionally, a commercial need for such PPE exists (industrial users of lasers or other intense sources of heat and radiant energy) and would help in driving down fabrication costs as the market grows.

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KEYWORDS: High energy laser; personal protective equipment; thermal

VERSION 3

A23B-T023 TITLE: Laser Power Beaming to Sustain Small UAVs

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Directed Energy, Microelectronics, Integrated Network System 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 section 3.5 of 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: Research and develop an innovative power beaming and receiver system to a small Unmanned Aircraft System (sUAS). Deliver a prototype demonstrating power beaming (PB) in a relevant outdoors environment.

DESCRIPTION: Unmanned vehicles are playing increasingly central and sophisticated roles on the battlefield and fulfill many different missions during both peace and wartime. Small autonomous vehicles like Group 1 sUAS represent a top DoD and Army priority, and are common in military formations, with wide distribution to units across the Services and in civilian agencies. These sUAS play a critical role in communication, situational awareness, etc. for squads and individual Warfighters, yet their battery lifetimes are limited to the 30-minute range [1,2], which curtails their mission effectiveness; it is unrealistic and cognitively burdensome to swap out batteries by hand every half-hour in a contested battlespace.

New laser and microwave directed energy technologies, including new receiver materials technology, enable “remote power”, where energy is transmitted to a vehicle’s receiver, using an intense, directed-energy beam [3-6]. The vehicle will be more mobile and lethal, not burdened by a heavy load of batteries and frequent battery swaps, and the unsustainable and vulnerable logistics load of extra batteries will be reduced or eliminated. Calculations, based on representative sUAS and onboard batteries, indicate that if 100 W could be continuously supplied to the sUAS batteries in-flight (implying > 100 W incident power on the sUAS receiver and even higher powers in the transmitted beam at the source), the mission lifetime of the sUAS could double to one hour, before the battery would need to be changed. If 200 W could be delivered onboard the sUAS to the battery, the sUAS could operate indefinitely, and the need for extra batteries greatly curtailed. Early demonstrations focused on a UAS relatively stationary in a wind tunnel [7]; a more applicable demonstration is needed.

Beaming power to a sUAS is technically challenging: a powerful beam must be continuously aimed at and confined within the sUAS-borne receiver for a long time, despite atmospheric turbulence and sUAS motion. Eye safety and the effect of the receiver on sUAS motion must also be considered. Photovoltaic receivers have been proven to be lightweight and efficient, especially for space and portable power applications. Photovoltaic cells for PB must also maximize power output and handle some amount of movement (due to atmospheric turbulence, sUAS motion, etc.) of the incident beam, and they must be thermally stable, not heating and losing efficiency excessively under continuous illumination by a powerful beam whose centroid wanders. Rectennas or bolometers are also possible receivers, especially for wavelengths in the short-wave infrared regime or longer. In all cases, new materials, robust to temperature swings and capable of delivering power, must be designed or reconfigured.

The goal of this Topic is to research and develop a novel PB system to extend the range of Group 1 sUAS (< 20 lb.) far beyond the current limitation of approximately one-half hour flying time for Group 1 sUAS, at least doubling it, while not negatively impacting mission (due to attached receiver) or generating significant safety issues (demonstrated outdoors in Phase II). Laser PB may be best for small Group 1 sUAS.

PHASE I: NOTE THAT IN-HOUSE CONTRACTORS (ORISE POSTDOCTORAL ASSOCIATES) WILL ASSIST WITH PROPOSAL REVIEW
Identifying, through early-stage experiments and modeling (not just modeling), a PB system that will provide at least 100 W continuous onboard a sUAS which is carrying out a simple mission (e.g., reconnaissance, or observing a fixed area), at a range of 500 m or more from the source. The PB system must have source, receiver, and sUAS technology with technical merit specified. The wavelength of the PB source and the receiver can be selected by the responding firm, as can the outdoors environment and mission scenario, but the sUAS must be "blue"; e.g., on the US government's permitted acquisition list. Model, and conduct initial experiments informing understanding of, power beaming to a sUAS. In reports, comment on eye safety, range, aiming stability, sUAS type, mission and scaling to faster re-charge times. Predict and justify a technical and programmatic path, based on modeling and initial experiments (not just modeling), of extending mission lifetime, ideally by 30 minutes with less than 60 minutes of charging and range of at least 500 meters. Employ preliminary experimental data, for example using a relevant laser in a laboratory.

PHASE II: NOTE THAT IN-HOUSE CONTRACTORS (ORISE POSTDOCTORAL ASSOCIATES) WILL ASSIST WITH PROPOSAL REVIEW Building on Phase I work, in Year 1 of Phase II: demonstrate a prototype, consisting of a full PB system and Group 1 sUAS with receiver, and demonstrate in a lab environment the power delivery to the sUAS batteries in an eyesafe manner. Also in Year 1, demonstrate receiver robustness under high power densities and interaction with a moving beam. In Year 2, demonstrate the full PB system outdoors in the relevant environment with the sUAS' executing a simple mission, like reconnaissance (moving in a straight line) or hovering or circling a protected area. Power levels should be at least 100 W onboard (not incident on) a sUAS, and the power must be demonstrated over a distance of at least 500 meters continuously. At the end of Phase II, demonstrate onboard delivery of 100 W to the sUAS battery over a range of at least 500 meters outdoors.

PHASE III DUAL USE APPLICATIONS: "Scale the technology demonstrated in Phase II up to a level that produces a full system that could be used for a sUAS mission, such as reconnaissance/situational awareness, in an operationally relevant environment for the Army, including probably larger range to 1 km and beyond. The technology must be of interest for the Warfighter and civilian (e.g., first responders) in challenging environments; for example, for reporting back to Warfighters and/or civilian emergency personnel situations in dangerous environments (battlefield, contaminated area, mines, etc.). Scale up the technology from Group 1 sUAS to much larger UAS that can travel across continents, especially where solar power cannot be relied on.

Dual use potential comes from (1) the great commercial potential of sUAS and UAS in general to deliver commercial products in an efficient and targeted way (2) the application of sUAS and autonomous assets in general to penetrate dangerous environments unfit for humans for reconnaissance and retrieval purposes, especially where remote power is advantageous because it would be dangerous and inefficient to change sUAS batteries by hand (e.g., environments contaminated by toxic chemicals or pollutants) and (3) the similarity of power beaming to other directed energy applications where the sUAS is flying in an unauthorized area (e.g., near an airport), and where law enforcement or military needs additional tools to defend the area. It is envisioned that this technology will benefit from large emerging civilian markets where remote power is increasingly sought as UAS travel further and are required to carry larger payloads."

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KEYWORDS: Power beaming, Remote power, Unmanned Aerial Vehicles, Autonomy, Photovoltaic, Receiver, Near-Infrared, Short-wave infrared

VERSION 3

A23B-T024 TITLE: Food and Water Sensor for Sustainment of the Joint Expeditionary Force

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

OBJECTIVE: Develop a multiplex detection system that can be used by an expeditionary force for the detection of pathogens in food and water using shelf-stable nanotechnology enabled assay

DESCRIPTION: U.S. troops are deployed worldwide to places where commercial food sanitation standards may be inferior with poor enforcement. Survey data of military personnel deployed in Iraq or Afghanistan reported high rates of diarrhea, 70 and 54% respectively, for respondents. Higher rates in deployed personnel in Iraq was attributed to more access to local foods (26.6% in Iraq reported eating local food weekly compared to only 5.3% in Afghanistan). There is significant risk to Warfighters consuming local food or water that contains pathogens. Pathogens can be naturally occurring or intentionally introduced. Current methods to detect pathogenic contamination in food/water such as culture counting, molecular diagnostics, and ELISA like assays require reagents with limited shelf-life, cold storage requirement, trained users, multiple manual steps, and long wait times. This topic seeks to utilize detection technologies to protect Warfighters from incidental or intentional contamination by verifying the safety of food/water. Reducing the logistical burden associated with acquiring safe food and water will maintain expeditionary posture on extended missions up to 7 days without resupply as part of multi-domain operations.

Current detection systems for food/water pathogens require multiple pieces of equipment for a pre-enrichment/concentration of target in the food sample followed by multiple steps to isolate the pathogen from the sample matrix. These procedures increase the testing time and ultimately extends the overall time to response. In addition, cold chain logistics is a key resource limiting factor that directly affects reagent stability and is not feasible for the expeditionary force. Recent advances in biotechnology, synthetic biology, nanotechnology, and artificial intelligence/machine learning provide opportunity to overcome many of these limitations and hurdles. The proposed concept would utilize a single hand-held test device that can provide a yes/no determination of food and water safety without the use of other supporting equipment elements in a resource limited environment. This system would be capable of targeting enteric viruses, parasites, and bacteria. Viral targets would include Hepatitis A, Norovirus, Poliovirus, Rotavirus and Coxsackievirus. Parasite targets would include Giardia, Cryptosporidium, Schistosoma, Entamoeba histolytica and Cyclospora. Bacterial targets would include Shiga Toxigenic Escherichia coli (STEC), Listeria monocytogenes, Salmonella, coliforms and Campylobacter.

The overall size and weight of the system should be man portable with the objective of each individual component to be hand-held (threshold total system weight of less than 5lbs with the objective weight of less than 3lbs). Stability of the system and reagents will need to be compatible with non-controlled environmental conditions to include extremes in temperature (low -40°F, high 160° F), freeze-thaw cycles, wide range of moisture condensing and non-condensing (RH% 10 to 90%). Shelf stability of reagents in the test kit is necessary and must not expire for at least one calendar year. System will provide a rapid (threshold time to response < 8 hrs, objective time to response < 2 hrs) yes/no determination of safety without the need for user interpretations. An internal positive control and negative control for system readiness and test reagent verification will also be key requirements of the final system.

PHASE I: Design and develop a proof-of-concept unit capable of demonstrating the performance requirements and metrics outlined above. Establish the feasibility, usability and practicality of the proposed design and materially demonstrate and validate the concept through preliminary testing. For Phase I the detection system would have to show the ability to detect one target from each group (virus, bacteria, and parasite) in water on a single test kit without using supporting laboratory equipment. Detection of the targets would occur at levels that are high enough that enrichment would not be needed for bacterial targets. Detection system in this phase will be a breadboard unit. A preliminary cost analysis must be completed based on projected scale-up and manufacturability considerations. A final report shall be delivered that specifies how requirements will be met (including mitigation of risks associated with factors limiting system performance). The report will detail the conceptual design, performance modeling and associated drawings (CAD or Solidworks® format), scalability of the proposed technology with predicted performance, safety and human interface (MANPRINT) factors, and estimated production costs. The projected technical readiness level (TRL) shall achieve a TRL of 3 and provide a clear path to Phase II/III and follow-on commercialization.

PHASE II: Refine the technology developed during Phase I in accordance with the goals of the project. Fabricate and demonstrate a high fidelity, full scale, advanced prototype for the target warfighter application, verifying that the desired performance is met. Expand detection to the other four organisms in each group that were not addressed during Phase I. Phase II will also include sampling of food matrices for all of the pathogens in each group. Food samples will include spinach, strawberries, and ground beef. Phase II will also maximize sensitivity improving on the detection limit established in phase I in water by lowing the detection limit by factor of 10 (Threshold) to 1000 (Objective). Minimize detection time for the assay (time to result; Threshold 8hrs, Objective less than 2hrs). Shelf stability of included reagents without refrigeration or other controlled environment will be addressed (shelf-life threshold 1 year, objective 5 years). Complete construction of full-scale prototype system meeting metrics for size (handheld), weight (Threshold 5 lbs., Objective 3 lbs.) and run time before recharge (i.e. battery life; Threshold 10 hr, Objective 24 hr) requirements. Provide a report, associated drawings and control software/source code, if applicable, documenting the theory, design, component specifications, performance characterization, projected reliability/maintainability/cost and recommendations for technique/system implementation. Deliver a high-fidelity full-scale prototype, consumables, and user guide to support joint Warfighter technical, operational, environmental and safety testing in the target application by the end of Phase II. An updated production cost analysis shall be completed and design for manufacture considerations shall also be projected to support advancement of TRL and associated Manufacturing Readiness Level (MRL). An implementation plan shall be provided for the scalable warfighter sustainment (food and water) sensor system and reagents for use by the joint expeditionary force. The Phase II prototype shall support operational testing that validates the feasibility of the approach and can ultimately support transition to military and commercial applications (Phase III). The projected technical readiness level shall be a TRL 6.

PHASE III DUAL USE APPLICATIONS: The proposed technology innovation and associated manufacturing capability will overcome the present technology gap and be rapidly transitioned to both military and commercial applications. The anticipated product is a self-contained, rapid, easy to use, shelf stable assay as part of an ideal detection platform for field use by expeditionary forces, as appropriate. The detection system in this phase will be a fully operational single process unit. The Phase III is expected to advance the proposed innovation to a TRL of 7 or higher, supporting a system demonstration in a relevant environment in the hands of the Soldier. Ultimately, the technology will be transitioned to the Squad or individual Warfighter, where high efficiency, long life, and low-cost technology is needed. This will maximize the performance, lethality and security of the Warfighter by ensuring safe and optimum hydration and nutrition in all operating environments. The Phase III represents concurrent (unfunded) commercialization of the technology that is expected to provide economy of scale, logistic, and other benefits that can be attributed to the proposed development. This technology will transition to Joint Project Manager Medical Countermeasure Systems – Diagnostics (JPM-MCS-dX) or Product Manager Soldier Clothing and Individual Equipment (PdM-SCIE). Commercially, this system can be used for rapid, simple identification of pathogens in food and water that may be contaminated with multiple pathogens. The system may also have potential use in point of care diagnostics for these targets in a medical environment.

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KEYWORDS: Nanotechnology, Biosensor, Food and water, Diagnostics, Pathogen detection, Multiplex, Shelf-stable reagents, Synthetic biology, Machine Learning, Artificial Intelligence