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ARMY STTR 21.C
PROPOSAL SUBMISSION INSTRUCTIONS

The approved 21.C 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 nine (9) 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 a virtual Army STTR Industry Day on 1 & 2 September 2021 to further delineate Army requirements and stimulate small business/research institute partnership-building. Please visit: www.armysttr.com for more information.

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 $173,000.00 over a period not to exceed six (6) months. **PLEASE NOTE THAT THE MAXIMUM DOLLAR AMOUNT HAS BEEN INCREASED COMPARED TO PREVIOUS PHASE I's**. Army STTR uses only government employee reviewers in a two-tiered review process unless otherwise noted within the topic write-up. Awards will be made on the basis of technical evaluations using the criteria described in this DoD BAA Preface and availability of Army STTR funds.

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

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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 volumes: Proposal Cover Sheet, Technical Volume, Cost Volume, Company Commercialization Report (CCR), Supporting Documents, and Fraud, Waste, and Abuse Training. **Please note that Volume 5 (Supporting Documents) and Volume 6 (Fraud, Waste and Abuse) are now required as noted on the DoD SBIR/STTR website for Phase I proposals.** Proposals not conforming to the terms of this BAA will not be considered. The Army has established a **5-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 should address: (1) identification and significance of the problem or opportunity, (2) Phase I technical objectives, (3) Statement of Work, (4) any related work being performed, (5) the relationship of the proposed work to future research or research and development and (6) the commercialization strategy. Information regarding key personnel, subcontractors and consultants as well as facilities and equipment should be included within the Technical Volume as it relates to the work to be performed; however, full technical resumes/biographical information, letters of support, and detailed descriptions of facilities and equipment should be reserved for inclusion in Volume 5, Supporting Documents. Any supporting information contained in Volume 5 should be referenced within the Technical Volume. Volume 5 should also include information regarding any prior, current, or pending support of similar proposals or awards, Contractor Certification Regarding Provision of Prohibited Video Surveillance and Telecommunications Services and Equipment and the Foreign Disclosure Addendum. 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 5-page limit. **Army STTR Phase I proposals submitted containing a Technical Volume over 5 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 5 page limit.** If you experience problems uploading a proposal, email the DoD SBIR/STTR Help Desk 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 Volumes: Proposal Cover Sheet, Technical Volume, Cost Volume and Company Commercialization Report, Supporting Documents to include Contractor Certification Regarding Provision of Prohibited Video Surveillance and Telecommunications Services and Equipment and Foreign Disclosure Addendum, Fraud, Waste, and Abuse Training. **Please note that Volume 5 (Supporting Documents) and Volume 6 (Fraud, Waste and Abuse) are now required as noted at the DoD SBIR/STTR website for Phase II proposals.** 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 $1,150,000. **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 $575,000; the second 12 months of funding should also be approximately $575,000. The entire Phase II effort should not exceed $1,150,000. 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 $575,000 if program funds are limited.

Any subsequent 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)), the Army will provide technical assistance services to small businesses engaged in STTR projects through a network of scientists and engineers engaged in a wide range of technologies. 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.

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The Army has stationed two (2) Technical Assistance Advocates (TAAs) across the Army to provide technical assistance to small businesses that have Phase I and Phase II projects with the participating Army organizations within their regions. Firms may request technical assistance from sources other than those provided by the Army and request TABA funding. Details related to TABA are described in section 4.19 of the DoD BAA. All such requests must be made in accordance with the instructions in Section 4.19. It should also be noted that if approved for TABA from an outside source, the firm will not be eligible for the Army's TAA support. 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@mail.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 **$173,000.00** 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.

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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 21.C Topic Index

Participating Organizations	PC	Phone
DEVCOM-Armaments Center	Benjamin Call	973-724-6275
DEVCOM-Aviation and Missile Center	Dawn Gratz	256-842-8769
DEVCOM-ARL/Army Research Office	Nicole Fox	919-549-4395
DEVCOM-C5ISR Center	Lauren Marzocca	443-395-4665
DEVCOM- Chemical Biological Center	Martha Weeks	410-436-5391
CoE-Environmental Research and Development Center (ERDC)	Melonise Wills	703-428-6281
Medical Research and Development Command (MRDC)	Danielle Wilson Amanda Cecil	301-619-3354 301-619-7296
DEVCOM-Soldier Center	Cathy Polito	508-233-5372
DEVCOM-Ground Vehicle Systems Center	George Pappageorge Joseph Delfrate	586-282-4915 586-282-5568

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ARMY STTR 21.C Phase I Topic Index

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A21C-T001 TITLE: Dual-use Secondary High Explosive and Rocket Propellant

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): 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: Dual-use energetic formulations that can serve as both secondary high explosives and rocket propellants to enable dual-purpose rounds capable of trading range and penetration for detonation.

DESCRIPTION: To date no formulation has been able perform as a propellant while offering PBXN-9 detonation velocity for terminal effects. Dual-use energetics offer the promise of an increased target set and extended range within the same round. This topic directly addresses the performance objectives of two Army Cross Functional Teams (CFTs). To this end, the topic requests novel materials for use as both a rocket propellant and a high explosive. The materials should enable development of a dual-use munition offering both an enhanced detonation mode and an extended-range/penetration mode. Such a munition would offer selectable effects through the use of an ignition element for the extended-range mode and a detonator for the high explosive mode. This development is expected to drive advancements in ignition and munition train technology, necessitating smart sensors to determine when the propellant should be detonated during flight.

PHASE I: Offeror should produce samples of at least four different formulations under consideration and perform small-scale testing to indicate the materials are safe to handle in suitable quantities. Thermal characterization must be conducted to determine if the material will have the stability requisite for the intended application. This process will also provide data such as enthalpy of combustion, detonation speed, and decomposition temperature. Thermochemical code calculations should be performed to produce initial estimates of the performance of these materials. Small-scale combustion and detonation tests are to be conducted to assess the relative performance of the developmental materials under consideration.

PHASE II: Offeror should produce two or three formulations (downselected based on input from Armaments Center) to perform larger scale testing. This process should incorporate tests such as cylinder expansion, detonation velocity and pressure, characterization of mechanical properties, critical diameter, gap sensitivity, strand burner tests (at various pressures), 2x4 inch thrust tests, and aging studies. This data should be evaluated to identify the best candidates for the intended application.

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PHASE III DUAL USE APPLICATIONS: Phase III will focus on a live-fire demonstration of the developmental formulation in a complete munition. This process will showcase a munition that demonstrates efficient use of the energetic payload in both modes. Other relevant testing such as IM testing, arena testing, set back testing, penetration depth, etc. will also be conducted as necessary depending on the needs of the item manager.

REFERENCES:

1. The chemistry of explosives, Jacqueline Akhavan;
2. Introduction to the technology of explosives, Paul Cooper;
3. Explosive Effects and Applications, Jonas Zukas, William Walters

KEYWORDS: Explosive, rocket, propellant, munition, secondary, lethality, range, dual use

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A21C-T002 TITLE: Gun-hardened, Hypersonic-capable RF Components for Smart Munitions

RT&L FOCUS AREA(S): Control and Communications, Hypersonics, General Warfighting Requirements

TECHNOLOGY AREA(S): Weapons, Electronics, 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: Investigate and develop innovative designs and technologies to incorporate RF transparent windows, conformal antenna technology, and supporting apertures on gun-launched smart projectiles with hypersonic capability.

DESCRIPTION: Advancements in the development of electromagnetic railguns and extended-range cannon artillery are paving the road for cost-effective engagement of land, sea, and air targets at extreme ranges. To unlock this capability, projectiles must incorporate advanced RF components such as multifunctional conformal antennas. Given the extreme aerothermal environment (>1000°C) and the system-level integration of hypersonic projectiles, these components must reside underneath an RF transparent window to survive and operate for the duration of flight. All components, manufacturing techniques, and integration concepts must also endure gun launch acceleration as high as 30,000 g.

PHASE I: Phase I will be a proof of concept study to determine the feasibility of RF transparent window and aperture assembly designs. Investigations should include analysis of potential aperture mounting configurations, ability of the antenna to transmit in S-Ku (2-18 GHz) band (gain, polarization, bandwidth, pattern coverage) through high-temperature compatible materials, survivability of window materials, and window application methods. RF performance shall be verified through simulation and breadboard antenna measurements. A final proposed concept design featuring a detailed description and analysis of both expected thermal and mechanical loads, shall be delivered at the conclusion of the phase I effort.

PHASE II: The proposer shall deliver two prototype radome/antenna assemblies integrated with the prototype antenna apertures in an existing large caliber projectile form factor with the proposed integrated RF transparent window or thermal protection system (TPS) solution. The design should ensure survivability of high shock and thermal loads without additional thermal protective systems or layers. The materials shall be designed for minimal impact to wave front distortion and boresight error. The design should also minimize weight, volume, and specialized handling and processes. The design will feature high-performance TPS composites for hypersonic window and radome applications with wide pass bands in the L through Ku band range (1-18 GHz) for various functions, including GPS navigation and guidance and terminal homing. Also of interest is operation up to W-band (94 GHz). The proposer must demonstrate launch survivability of window materials. The proposer must also conduct multi-minute extreme thermal testing of window/aperture assemblies to include electromagnetic measurements during testing to ensure the apertures can avoid failure or degradation underneath a high-temperature window. Integration with system-level thermal protection systems should also be explored.

PHASE III DUAL USE APPLICATIONS: The proposer must coordinate with prime contractors and all service components to fully develop, integrate, and test the performance and survivability characteristics of the design for integration into extended-range Army platforms and joint development efforts. This technology with be a strong candidate for product improvements to munitions in service with the service components.

REFERENCES:

1. Santamaria, Maj. Paul & Draheim, Capt. Steve. Acquisition, Army ALT Magazine. “PEO Ammunition, ARDEC and the Army Rapid Capabilities Office come together at Picatinny Arsenal” https://asc.army.mil/web/news-alt-jas-18-long-range-short-term/;
2. 256 120mm Smoothbore Gun, www.inetres.com/gp/military/cv/weapon/M256.html

KEYWORDS: Hypersonic, projectile, radio frequency, communications, munition, artillery, sensors, high-temperature materials, antenna

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A21C-T003 TITLE: Development of Vat Polymerization Materials for Additive Manufacturing of Gun Propellant

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): 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: Develop techniques to incorporate energetic solid filler such as HMX, RDX, or Nitroguanidine (NQ) with feedstock for additive manufacturing of gun propellant.

DESCRIPTION: This development effort focuses on materials to enable 3D printing of gun propellants. Additive manufacturing presents the opportunity for performance gains through highly engineered complex structures. These structures offer the potential for increased loading densities and higher surface area progressivity. These properties, in turn, translate to extended range for existing weapon platforms.

The developmental materials must match the high-strain-rate mechanical properties of JA2 propellant while providing propellant performance characteristics that match or exceed those of M31A2. The threshold energy level is a calculated impetus of 950 J/g with an objective level of 1100 J/g. The materials should also have superior low-temperature properties to avoid brittle fracture (glass transition below -50 Deg F, Tg) and should retain shape up to 145 deg F. This level of will likely be achieved through the addition of the energetic fillers. Materials can be a mixture of various polymers and additives.

The proposed solution must not produce toxic combustion products and those that result in excessive residue and erosion. Oxygen balance and ignition properties must also be considered up front for this solution to be viable for defense applications.

PHASE I: Demonstration of achieving greater than or equal to 75% solids loading by mass of filler with 1.7 - 1.9 g/cc density and nominal particle size of 10 micrometers. Second and equally weighted deliverable is demonstration of utilizing a commercial off the shelf or custom 3D printer that uses vat photopolymerization methods to obtain samples for testing. Third is characterization of preliminary mechanical properties including uniaxial compression results at high strain rates (1/100 seconds) and associated material characterization (density, microscopy, physical, chemical, etc.). If the capability to demonstrate at 1/100 seconds is unavailable in the private sector, lower strain rates with accompanying analysis may be used to extrapolate results. Alternatively, proposer may submit the material for evaluation at US government facilities at no charge. Additionally, cure/penetration depth of development materials must demonstrated and provided.

PHASE II: Required Phase II deliverables would be scale-up of feedstock and delivery of said feedstock in a quantity greater than 500 ml. to a government and/or contractor facility for further performance evaluation. Subscale evaluation of said materials in both mechanical and combustion testing would be required to corroborate the results of phase I. The contractor stablished resolution limits, delivering sample calibration prints of said materials (and associated analysis) with proposed printing methods utilizing vat photopolymerization (selected during phase I).

PHASE III DUAL USE APPLICATIONS: The end state of this research would be a material feedstock that balances high-performance combustion characteristics and superior mechanical properties in the extreme gun environment during the interior ballistic event. The target US Army application would be the 155mm Artillery platform due to the need for extended range.

This technology will be transitioned to GOCO ammunition plants such as Radford Army Ammunition Plant, and will benefit from early engagement with the prime contractors operating these facilities.

Commercial applications of this material include dental use (highly dense and highly filled materials), high performance composites, clean burning pyrotechnics (fireworks), and any application where a consumable 3d Printed object is needed.

REFERENCES:

1. Photopolymerization processes of thick films and in shadow areas: a review for the access to composites; Patxi Garra, Céline Dietlin, Fabrice Morlet-Savary, Frédéric Dumur, Didier Gigmes, Jean-Pierre Fouassier and Jacques Lalevée; Polymer Chemistry - Royal Society of Chemistry 2017; Polym. Chem., 2017, 8, 7088;
2. Office of Naval Research ONR Scientific Officer: Steven G. Fishman; 01 January 1993- December 31, 1994; Final Technical Report August 25, 1997;
3. Preparation and Properties of Dental Composite Resin Cured under Near Infrared Irradiation; Motohiro Uo, Eiki Kudo, Aya Okada, Kohei Soga and Yasuo KOGO; Department of Biomedical Materials & Engineering, Hokkaido University, Sapporo 060-8586, Japan, Department of Material Science and Technology, Tokyo University of Science, Chiba 278-8510, Japan; mail@m-uo.com;
4. CHARACTERIZATION OF CURING KINETICS AND POLYMERIZATION SHRINKAGE IN CERAMIC-LOADED PHOTOCURABLE RESINS FOR LARGE AREA MASKLESS PHOTOPOLYMERIZATION (LAMP) A Thesis Presented to The Academic Faculty by Kiran Kambly In Partial Fulfillment Of the Requirements for the Degree Master of Science in Mechanical Engineering Georgia Institute of Technology Dec, 2009

KEYWORDS: 3D printing, additive manufacture, gun propellant, gun propulsion, combustion, highly filled material, highly filled composite, high performance photopolymer, photopolymer, toughness

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A21C-T004 TITLE: Energetic Polymer Systems for Additive Manufacturing Explosive and Propellant Formulations

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Weapons, 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: Develop and demonstrate energetic ingredients for polymer resin systems (monomers, plasticizer(s), related additives) for use in explosive and propellant formulations with additive manufacturing capabilities.

DESCRIPTION: The US Army has a need to develop energetic formulations suitable for additive manufacturing (AM) based on printing technologies such as direct-write extrusion and vat polymerization. To enhance the energetic performance and printability of these formulations, new energetic ingredients for AM resin systems are desired. Specifically, these include energetic monomers, crosslinkers, and plasticizers. Although additive manufacturing techniques are largely recent developments, energetic polymers and plasticizers have a relatively long history. Their purpose has generally been as components in chemically cured energetic formulations such as explosive “cast-cure” or polymer-bonded explosives (PBX), where energetic monomers and plasticizers are blended with high-solids loadings of explosive materials (e.g. RDX) and chemically cured into a desired shape/configuration. Existing energetic polymer examples include glycidyl azide polymer (GAP) and poly(3-nitratomethyl-3-methyloxetane) (polyNIMMO). Plasticizer examples include nitroisobutanetriol (NIBTN), bis(2,2-dinitroproplyl) acetal/formal (BDNPA/F), and triethylene glycol dinitrate (TEGDN). In general, these materials often suffer from drawbacks such as poor mechanical properties, stability or sensitivity issues, lower achievable solids-loading, production difficulties, and/or low energetic performance. They were also not developed with next-generation additive manufacturing technologies in mind. Printing techniques such as direct-write extrusion and vat polymerization typically require curable resin systems with appropriate rheological properties, controllable curing and good interlayer adhesion. To both provide higher energetic performance and better align with these AM technologies, new high energy-density, curable polymeric resin materials are required to push the envelope of energetic performance while enhancing stability and improving producibility.

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PHASE I: With the goal of working towards one or more complete, curable, high-performance energetic resin system(s), design and determine the technical feasibility for producing novel, AM-applicable energetic resin ingredients to include one or more of the following: energetic monomer(s), energetic polymer(s), energetic plasticizer(s), and/or related additives including photoinitiators and other curatives. Perform theoretical energetic calculations to establish predicted performance and aid in the selection of materials. Develop synthetic approaches to the materials and produce small lab-scale quantities of materials for characterization and safety screening. In addition to strong energetic performance and safe handling, selected materials should be chemically compatible with traditional military explosive ingredients (e.g. nitramines) and munition housing materials (e.g. stainless steel).

PHASE II: Required Phase II deliverables will include the formulation of the identified Phase I energetic polymeric materials into complete chemically-curable energetic resin systems suitable for AM processing. Develop and demonstrate scale-up of down-selected ingredients to the pilot production scale. Evaluate printing of specific parts to demonstrate printability of the resin system. The small business will ship 100 gram samples of the resin system(s) to DEVCOM Armaments Center for verification of product quality and suitability for AM processing.

PHASE III DUAL USE APPLICATIONS: The pilot processes developed in Phase II will be scaled up to the production level. Military applications will focus on explosive and propellant charges. Commercialization areas potentially include the construction, mining, and space industries.

REFERENCES:

1. Provatas, A., Energetic Polymers and Plasticisers for Explosive Formulations—A Review of Recent Advances, Technical Report DSTO-TR-0966, Defence Science and Technology Organisation (DSTO), Aeronautical and Maritime Research Laboratory, Melbourne, Victoria, Australia, April 2000, https://apps.dtic.mil/dtic/tr/fulltext/u2/a377866.pdf;
2. Ligon, S. C.; Liska, R.; Stampfl, J.; Gurr, M.; Mulhaupt, R., Polymers for 3D Printing and Customized Additive Manufacturing. Chem. Rev., 2017, 117 (15), 10212-10290;
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KEYWORDS: Additive manufacturing, explosive formulation, propellant formulation, energetic plasticizer, energetic polymer

VERSION 3

A21C-T005 TITLE: Protective Nanostructured Coatings to Enable Consistent Lubricity in Engines using F-24 Fuels

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials

OBJECTIVE: Develop a coating for engine fuel systems that will form a protective tribofilm that enables higher-pressure fuel systems to accommodate the variations possible in F-24 fuels.

DESCRIPTION: The increasing use of unmanned ground and aerial vehicles has exposed the need for higher performance engines for these systems. Increasing the performance of these engines requires operation at higher fuel pressures, which creates a challenge related to fuel lubricity. Sufficient fuel lubricity in the engine fuel systems is a necessity for effective operation. At higher pressures that need is more acute, as insufficient lubricity could lead to catastrophic failure due to wear or damage. Most of these vehicles use F-24 jet fuel. There are many different blends of F-24 due to variations in the base fluid and contaminants present. This makes it very difficult to employ in higher-pressure common rail engines, as they may not have sufficient lubricity under all the potential F-24 formulations available. It may not be possible to obtain the ideal formulation of F-24 in the field, and the use of an unsuitable formulation may impair or damage the engine. For higher-pressure fuel systems to be practical in a logistical sense, a solution that enables consistent lubricity for these engines under a variety of conditions and formulations is required. The most practical solution would be a coating that provided protection and sufficient lubricity to the engine parts during operation by formation of renewable protective coatings.

A recently proposed solution is the use of coatings that form self-lubricating carbon-based diamond like coatings due to catalytic breakdown of hydrocarbons and contaminants in the fuel [1,2]. This previously was very difficult as these catalysis reactions are facilitated by the use of precious metals such as platinum and gold [3]. In addition, the coating also had to be nanostructured to obtain the desired level of interaction with the organic compounds in the fuel. Recent publications, however, have established it is possible to create nanocrystalline coatings using physical vapor deposition and sputtering techniques [4]. In addition, advances in the field of nanocrystalline alloy design have led to the discovery of a number of potential nanocrystalline alloy compositions that are suitable to fabrication via sputtering or other surface coating techniques [5]. This opens up the possibility of creating a stable nanocrystalline coating using more cost effective alloying elements. In fact, there have been recent publications demonstrating protective tribofilm formation using coatings containing Co, Mo, Cr, Al, and other alloying elements [1, 6]. This makes it plausible that a practical nanocrystalline alloy that forms protective tribofilms during engine operation could be developed for wide scale employment in the field.

While some coatings have been demonstrated in the laboratory, there is still a great deal of development required before they can be utilized in an engine fuel system. Any coating used for this application must be stable under a variety of conditions and robust under mechanical stresses. The tribofilm formed must be protective, otherwise the coating would prematurely wear and cause the engine to fail. In addition, the processing challenges related to industrial scale application of the coating and consistent application to complex geometries have to be addressed.

PHASE I: The offeror(s) shall develop a coating for AISI 52100 steel that will form protective tribofilms in alkane based fuels. A composition shall be selected that will form a stable nanocrystalline structure, not utilize precious metals such as platinum, palladium, and gold, and be mechanically stabile under load. The mechanism used to create the tribofilm can be based on any type of or combination of mechanisms (e.g. compositional, morphological, mechanical, etc.). However, the tribofilm created should provide protection for the coating and the steel and renew through continuing interactions with the fuel. The coating itself should not require reapplication for long-term function. The final deliverable shall be at least one candidate coating composition, lubricity testing results, and evidence of tribofilm formation. The coating shall be applied to a ball of AISI 52100, and tested for lubricity under following conditions: 1) in comparison to the standard hardened AISI 52100 ball, 2) with at least two fuels selected from diesel, Jet-A, and F-24, 3) using fuel lubricity standard ASTM D6079 (High-Frequency Reciprocating Rig), and 4) using fuel lubricity standard ASTM D5001 (Ball-On-Cylinder Lubricity Evaluator). F-24 can be obtained from the Army sponsor.

PHASE II: The offeror(s) shall continue to refine the coating composition, and begin to develop the processing approach for uniform application of the coatings to conformal and complex parts. The compositions identified in Phase I should be adjusted to be suitable for wide scale industrial fabrication. The offeror(s) should select a processing approach, and develop methodologies for uniform application of the coating on conformal AISI 52100 steel parts relevant to high-pressure fuel pumps. The final deliverables shall be four components (pumping piston, piston bore, small crowned cylinder, large cylinder) of a pump rated to reach 1500 bar or greater, with the coating uniformly applied to all contacting surfaces and tested for lubricity in two mechanical interfaces. Interface 1: One piston/bore conformal interface shall be tested with coating on the external surface of a piston and internal surface of a bore (both 5 to 8 mm diameter with clearance of less than 2 micrometer between piston/bore), reciprocating between 1-cm and 2-cm axial interface length, at a reciprocating frequency of at least 30 Hz. Interface 2: One cam-like interface shall be tested between a coated crowned cylinder of 5 to 8 mm sliding on a larger coated cylinder at 4 m/s. Lubricity testing in these two interfaces shall be conducted: 1) in comparison to hardened AISI 52100 steel in the same geometries and conditions, and 2) with three fuels (diesel, Jet-A, and F-24). Alternatively, the coating may be applied to components of a commercial high-pressure fuel pump with an oblong, rotary cam system capable of reaching 1500 bar fuel pressure, to include the pumping piston/cylinder and sliding interfaces of the cam system, and demonstrated with respect to an unmodified pump under conditions similar to those for the two interfaces.

PHASE III DUAL USE APPLICATIONS: The technology will support reliable engine operation of internal combustion reciprocating engines for Class II and III Unmanned Aerial Systems, for medium-sized ground vehicles, and for generators. The offeror(s) will adapt the processing technology to apply it to existing engine fuel systems. Coatings for other metallic alloys or composite materials will be developed. The process will be adapted so that engine components with the protective component are commercially available to researchers working on high-pressure fuel systems designs. The coatings could either be used to modify commercially available high-pressure fuel system components in an aftermarket process, or the coating could be integrated into new fuel system designs.

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KEYWORDS: Coatings, fuel lubricity, catalysis, tribology, nanostructured coating, active coating

VERSION 3

A21C-T006 TITLE: Automated Subscale Ballistic Test Platform

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials

OBJECTIVE: Develop, optimize, and demonstrate the use of high-throughput, sub-scale ballistic test setup that incorporates automated or autonomous functionality to maximize both data output and fidelity relative to full-scale ballistic testing.

DESCRIPTION: Data-driven materials design is a burgeoning field with the potential to rapidly accelerate new materials development, provided that large volumes of data can be efficiently generated and analyzed. The Department of Defense (DoD) is interested in data-driven design of next-generation protection materials. However, ballistic evaluation of protection materials presents a significant bottleneck: due to safety concerns and stringent testing requirements (e.g., the V50 ballistic test for armor as described by DoD MIL-STD-662F), full-scale ballistic tests are expensive and generate data at a very low rate, on the order of 10 samples/day. Sub-scale ballistic testing (e.g., laser-driven micro-projectiles, air gun-driven microbeads, electric-discharge-driven flyer plates) offers a potential route around these limitations, with the ability to use dramatically smaller projectiles and smaller samples to improve safety, expense, and significantly increase throughput. Nonetheless, sub-scale ballistic data collection is still relatively slow—alignment and calibration are exhaustively hands-on processes that could benefit from automation—and analysis is still done manually and post mortem. For example, fragmentation analysis, a valuable proxy for impact performance of brittle protection materials, is still done by manually collecting and analyzing each fragment that results from the subscale ballistic impact. Importantly, the accuracy of sub-scale methods against full-scale ballistic tests must be further evaluated: equivalent testing standards do not yet exist, and sub-scale techniques are only valuable so far as they provide accurate information about the real-world ballistic performance of a protection material. This situation warrants a concerted effort to enable high-throughput sub-scale ballistic testing and carefully evaluate its fidelity.

The goal for this effort is to develop a sub-scale ballistic testing platform as a critical tool for data-driven, high-throughput design and characterization of next-generation protection materials.

PHASE I: Define and develop an approach for high-throughput sub-scale ballistic testing of macroscale protection materials. The specific sub-scale method is not prescribed, but must be capable of creating ballistic, high loading rate (i.e. between 104 and 107 s-1) mechanical testing conditions that serve as an accurate proxy for a full-scale ballistic test. Specific capabilities that are desired include: in situ quantitative characterization and analysis capabilities that provide as good or better determination of ballistic performance as traditional post mortem manual analysis or conventional failure probability analyses, like V50. The approach should also be capable of automation (e.g., in sample preparation/loading, alignment, data processing, etc.) to maximize testing and data throughput: the concept must demonstrate a 10-fold improvement in the rate of experimentation over manual subscale ballistic testing, and a 100-fold improvement over full scale ballistic testing conventionally used to satisfy V50/MIL-STD-662F. Note that the approach is not intended to replace ballistic testing standards, but rather shall complement existing standards by enabling rapid screening of materials. The method should be tailored for research and development of next-generation hard protection materials based on ceramics, composites, and/or metals (as opposed to soft materials like polymers, or low-dimensional materials like graphene), and must serve as an accurate surrogate for full-scale ballistic testing while simultaneously enabling safe, high-throughput data generation and collection for data-driven design of advanced protection materials. The concept must also outline an approach for qualifying the accuracy of the method with respect to predicting material performance under full scale ballistic testing based on MIL-STD-662F. If awarded the Phase I option, the small business will demonstrate the feasibility of the proposed concept/approach. Develop a Phase II plan.

PHASE II: Based on Phase I results, develop, demonstrate, and validate the proposed high-throughput test apparatus for sub-scale ballistic testing. The accuracy of the automated in situ approach will be quantified relative to a manual post mortem approach to data analysis, using the same sub-scale ballistic technique. The test must demonstrate a 10-fold improvement in the rate of experimentation with respect to manual subscale ballistic testing, and a 100-fold improvement over full scale ballistic testing to satisfy V50/MIL-STD-662F. The technique should encompass one or more of the following projectile geometries: highly planar flyer plates, spheres, and/or projectiles with ogived noses. The technique should enable various angles of target obliquity with respect to the vector of projectile velocity. High throughput data generation should be leveraged to facilitate data-driven inferences about the behavior and design of protection materials. The fidelity of the sub-scale technique and these inferences will be evaluated with select full-scale ballistic tests for V50/MIL-STD-662F. It is recommended that the performer work with government laboratories and/or established testing agencies to perform these select ballistic tests. It is also recommended that the performer work with bulk material vendors/Original Equipment Manufacturers (OEMs) and/or ballistic testing agencies to facilitate transition for Phase III. Successful completion of Phase II shall include a demonstration to DEVCOM Army Research Laboratory scientists and engineers engaged in ballistic testing of protection materials.

PHASE III DUAL USE APPLICATIONS: The completion of this effort would provide an automated tool that receives, prepares, assesses, and analyzes the ballistic performance of subscale samples in a way that accurately reflects the global behavior of the bulk material. Phase III will transition high throughput sub-scale ballistic testing techniques to commercial suppliers through bulk material vendors, OEMs, or other partnering agreement(s). Commercialization of this technology may be through the development of kits or modules for retrofitting existing subscale ballistic testing apparatus, or through the development of full turn-key systems. If successful, this technology would provide DoD engineers with a platform for rapidly assessing the ballistic performance of next generation armor materials.

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KEYWORDS: Ballistic test, armor design, subscale testing, data-driven design, protection material, automation, machine learning, autonomous experimentation, high-throughput experimentation

VERSION 3

A21C-T007 TITLE: Fast, frequency-agile, stimuli-responsive, and tunable (FAST) optical filters

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop, optimize, and demonstrate fast, frequency-agile, stimuli-responsive, and tunable optical filters that autonomously protect sensors from damaging optical beams, while allowing unobstructed transmission of non-damaging wavelengths and intensities.

DESCRIPTION: The Department of Defense (DoD) increasingly relies on advanced imaging technologies to perform critical functions like intelligence, surveillance, and reconnaissance (ISR) and positioning, navigation, and timing (PNT). Advanced imaging sensors—like electro-optical/infrared (EO/IR) cameras and micro-bolometers—will dramatically proliferate as DoD continues to modernize with autonomous platforms such as the Army's Next Generation Combat Vehicle. However, these sensors are vulnerable to inadvertent and adversarial electromagnetic (EM) attack: future operating environments will be replete with a wide range of EM waves of varied frequency and intensity, many of which could temporarily or permanently blind or damage imaging systems.

The ability to control strong light-matter interaction in liquid crystals[1], metamaterials [2-5], epsilon-near-zero (ENZ) materials [6,7], phase change materials (PCMs) [8,9], micro-electromechanical systems (MEMS) [10],and soft materials [11-14] suggest that these state-of-the-art materials systems can be leveraged to create tunable filters that autonomously respond to EM attack. For example, spatial light modulation (SLM) by metamaterials, holography, and liquid crystals enables selective-area light attenuation [1,2]. Digital metamaterials offer lenses and phase modulators capable of light redirection and beam steering [3,4]. Non-linear optical responses in Bragg reflector stacks and ENZ materials provide another potential route to autonomous light attenuation [5-7]. Integrating these concepts with PCMs, MEMS, and micro-mirrors may reveal new opportunities and platforms for programmable SLM and beam steering [8-10]. Finally, soft materials like liquid crystal elastomers and photo-responsive hydrogels have recently emerged as new platforms for autonomous manipulation of light [11-14], offering new abilities to create nano/microstructures that move in response to light and platforms for trapping and guiding laser beams. New capabilities in nano-/microfabrication may enable new, hierarchical approaches that combine multiple stimuli-responsive materials and architectures to further enhance adaptability.

If under EM attack, an imaging system must incorporate a filter that rapidly senses an EM wave, determines its wavelength, and autonomously responds to attenuate or re-direct the wave if necessary. This capability is necessary over broad spectral ranges, including ultraviolet, visible, short-wave infrared (SWIR), and long-wave infrared (LWIR). An ideal intelligent filter mechanism would be (1) Operable in typical battlefield conditions; (2) Compatible with dynamically reconfigurable and/or multi-spectral imaging systems; (3) Low-cost, to enable wide adaptation across the DoD; (4) Adaptable to different imaging architectures; and (5) Non-disruptive to imaging performance (e.g., range, resolution, frame-rate, etc.). This topic seeks innovative materials approaches to creating such filters, based on passive material-based intrinsic responses and/or active feedback circuits incorporating tunable materials. Adaptive filters should autonomously detect changes in operating conditions and/or EM-based insults (e.g., a change in lighting conditions vs. incident laser beams) and respond appropriately by physically dimming, shuttering, switching, filtering, blocking, and/or rejecting the dynamic light conditions. The response should further be localized to the incident beam or spot where appropriate, to maintain an unobstructed field-of-view for the rest of the imaging system. Finally, there is also a significant need for scaled-up manufacturing capacity and yield—the desired adaptive filters should be amenable to integration with imaging sensors with minimum added size, weight, power, and cost (SWaP-C).

PHASE I: Design a concept for candidate FAST filters and describe the proposed materials systems, architectures, and control schemes that will be employed. Perform ab initio atomistic modeling, full wave EM simulations, quasi-static simulations, finite element analysis, and/or technology computer-aided design (TCAD) as needed to demonstrate the feasibility of the proposed approach. Outline the techniques and procedures that will be used to fabricate the proposed design and characterize its dynamic filtering performance. Develop an approach to integrate the proposed FAST filter with a desired sensor technology, imaging platform, or form factor, selected from the following: focal-plane array (flat or curved), optical windows and lenses, glasses, contact lenses, goggles, or visors. As appropriate, create a partial prototype that demonstrates the functionality of one or more of the proposed design elements: the dynamic materials system, the filter architecture, the control scheme (if applicable), and/or the integration scheme.

FAST filter designs should inherently address or be easily adaptable to operate in the visible (380 – 780 nm) and the short-wave infrared (SWIR, 780 – 3000 nm) portions of the EM spectrum. Ultraviolet (UV, 100 – 380 nm) and mid-/long-wave infrared (MWIR/LWIR, 3000 – 14000 nm) light are also of (secondary) interest. The filtering mechanism should be dormant under normal imaging conditions, with optical transmission of 70 – 80% or greater at the nominal imaging wavelengths. The filter should autonomously respond to respond to high-fluence light (e.g., a high-power laser with a fluence on the order of 1 J/cm2) above the damage threshold of the imaging system should be interdicted by the filter changing its optical density (OD) by 3 or more (i.e., less than 0.1% of the incident laser energy should reach the sensor). The filter responses should be as localized to the incident spot size, in order to allow uninterrupted imaging while obscuring the sensing element(s) beneath the incident spot. These filter responses should be fully reversible, and the response time, including recovery to normal imaging conditions, should be no longer than 50 milliseconds. Articulate feasible pathways to response times of 1 nanosecond or less.

Secondary considerations for FAST filter design include: 1) Low fluence light (e.g., changes in lighting conditions caused by shadows or moving between indoors and outdoors) should cause the filter to remain passive so that the imaging system can automatically adjust to lighting conditions; 2) Medium fluence light (e.g., an adversarial laser-based sensor or probe) should be fully absorbed, redirected, or otherwise mitigated to cloak the imaging system.

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PHASE II: Based on Phase I modeling and proofs of concept, fabricate, test, and demonstrate at least one operational FAST filter prototype. The prototype should be capable of autonomous optical responses with sub-ns response times. The FAST filters should reversibly cycle over 105 times without suffering more than 2% degradation in response time, OD change, reflection, transmission, dormant state/position, etc. Using a detailed analysis of system trades and input from appropriate stakeholders, propose a pathway to refine and integrate the FAST filter prototype with a candidate imaging system of interest to or used by the Army. Depending on the target imaging system, the FAST filters should increase the total SWaP-C burden by 0.1% or less, should not adversely impact imaging performance, and should allow normal imaging modality over typical ranges of brightness/lighting conditions; more specifically, FAST filters under normal imaging conditions should not change the system's modulation transfer function by more than 10%, and should not change transmission of imaging wavelengths by more than 20%.

PHASE III DUAL USE APPLICATIONS: Phase II should demonstrate a FAST filter that is appropriate for implementation with existing and/or future Army imaging systems. Phase III will transition the newly developed FAST filter technology to commercial availability through the prime contractors that build these imaging systems, the original equipment manufacturers that manufacture sensing components, other relevant suppliers, and/or other partnering agreement(s), as appropriate. Commercialization of this technology may occur via the incorporation of one or more FAST filters anywhere in an imaging system (e.g., windows, lenses, shutters, FPA pixels, 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 an imaging system that autonomously responds to EM attack with no added cognitive burden to the user, and a minimum added SWaP-C burden. Expected dual-use applications include autonomous vehicles, LiDAR, border security, and protecting civilian optical imaging systems (e.g., thermal imaging of the sun).

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KEYWORDS: Metamaterials, phase-change materials, epsilon-near-zero materials, dynamic filters, optics, spatial light modulation, focal plane array, sensors

VERSION 3

A21C-T008 TITLE: Low Noise, High Saturation Power Semiconductor Optical Amplifiers (SOAs)

RT&L FOCUS AREA(S): Microelectronics

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: To develop semiconductor optical amplifiers (SOA), with performances that match or exceed those of Erbium-doped fiber amplifiers, for potential applications in photonic integrated circuits and photonic systems.

DESCRIPTION: The Erbium-doped fiber amplifier (EDFA) [1] has been the workhorse in commercial (e.g., long-haul fiber-optic communication systems) and defense (e.g., high power lasers) applications for more than three decades. The reasons for the success of EDFAs are low noise figure, large gain bandwidth, high saturation power, and low polarization dependence. The EDFA is typically pumped by either a 980 nm or a 1480 nm semiconductor laser diode, which already contains an optical amplifier, namely, the semiconductor optical amplifier (SOA). For the last two decades, the photonics industry has tried, in vain, to displace EDFAs by SOAs to reduce the cost as well as SWaP (size, weight and power). One of the main drawbacks of the SOA, in comparison with the EDFA, is its noise figure. Commercial SOA initially had noise figures above 6 dB due to coupling losses from the SOA waveguide to the optical fibers [2]. Recent efforts in reducing the coupling loss has results in SOA noise figures approaching 5 dB [3]. However, EDFAs can routinely maintain noise figures around 4 dB. The disadvantage in noise figure for SOAs is due to the fundamental noise processes of the semiconductor gain medium, and therefore, requires novel solutions to overcome. Another issue with SOAs is the low saturation power. Compared to the EDFA, the active region of the SOA has a cross-sectional area on the order of micron squared whereas the active region of the EDFA has a cross-sectional area on the order of 100 micron squared. To date, commercial SOAs can offer saturation power around 15 dBm, much lower than EDFAs [4]. The third disadvantage of the SOA is its polarization-dependent gain since, naturally, the quantum-well active region favors the transverse-electric mode in the amplification processes [5]. These three disadvantages, however, have not stopped the photonic industry's pursuits of eventually replacing EDFAs by SOAs. One such recent example is the use of broadband SOAs for digital coherent optical communication, in which one broadband SOA can replace three EDFAs in the S, C, and L band, respectively [6]. Nevertheless, the fundamental disadvantages of the SOA clearly hindered such efforts. For example, the polarization-dependent gain was reduced by using the complicated polarization-diversity configuration, which significantly increase the complexity of the device [6]. The relatively high noise figure also prevented the SOAs from being used for long-haul transmission. If the drawbacks in noise figure, saturation power and polarization sensitivity can be overcome, SOAs can have a tremendous impact on defense and commercial applications. Low-noise, high-power SOAs are extremely desirable in photonic integrated circuits such as RF photonic phased arrays for radars, microwave photonic filters and processors for electronic warfare, as well as high-power direct laser diodes. The purpose of the STTR program is to support the development of novel SOAs that can replace EDFAs at least in certain applications scenarios.

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PHASE I: To design, fabricate and characterize an SOA with optical gain of up to 20 dB or more with noise figure below 5 dB, saturation power above 20 dBm in the C band. In addition, provide a design that will further reduce the noise figure to below 4.5 dB and polarization-dependent gain to below 2 dB, and increase saturation power to above 27 dBm in the C+L band. Specifically, to formulate novel SOA device structures to reduce the noise figure and increase the bandwidth and saturation power.

PHASE II: To design, fabricate and characterize an SOA with optical gain of up to 20 dB or more with noise figure below 4.5 dB, polarization dependence below 2 dB, saturation power above 27 dBm in the C+L band. Demonstrate the application of SOA for analog/digital photonic links and photonic signal processors. In addition, provide a design that will further reduce the noise figure to below 4.0 dB, and increase saturation power to above 30 dBm in the S+C+L band, with low polarization-dependent gain. Production-scale costs of the SOA should be studied to show viability for reasonable cost reduction at manufacturing volumes. Motivation for phase III follow-on investment should be made evident.

PHASE III DUAL USE APPLICATIONS: Pursuit system-level defense and commercial applications based upon the SOAs developed in phase II. Clearly identify the advantages of the novel SOAs over EDFAs and other existing SOA structures. The photonic system employing multiple SOAs developed in this program should be integrated at a military installation or on a military platform in potential applications scenarios including but not limited to communications, electronic warfare, sensing and directed energy. Dual-use applications of the SOA in digital coherent fiber-optic communication systems and high-power laser systems are encouraged.

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KEYWORDS: Optical communications, high power laser, Semiconductor Optical Amplifier (SOA), erbium doped fiber amplifier (EDFA), laser diodes

VERSION 3

A21C-T009 TITLE: Millimeter-Wave MIMO and Micro-Doppler Radars for UAS Detection, Classification and Tracking

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Electronics

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 low-cost, small-size multiple-input multiple-output (MIMO) radar at millimeter-wave frequencies capable of analyzing target micro-Doppler signatures for detection, classification and tracking of unmanned aerial systems (UASs) in highly cluttered environments.

DESCRIPTION: Proliferation of UASs, more commonly referred to as drones, is emerging as one of the largest threats to the US Army's mission. These systems could provide US adversaries with a low-cost means of conducting intelligence, surveillance, and reconnaissance missions against or even attacking US forces. Many small UASs cannot be detected by traditional air defense systems due to their size, construction material, and flight altitude.

Conventional microwave systems for detecting small airborne threats, such as counter rocket and mortar (C-RAM) radars, rely on high target speed to reject clutter but face challenges for low, slow, small UASs. The greater Doppler sensitivity and narrower radar beamwidths can be achieved at millimeter-wave (MMW) (30-300 GHz) frequencies could potentially enable detection and resolution of slower objects in more complex terrain. Larger radar bandwidths allow high range resolution, which can facilitate the classification and tracking of slow moving objects. MMW offers additional advantages over optical and infrared parts of the electromagnetic spectrum. MMW has good penetration characteristics in the presence of fog, smoke or dust. Radars are active sensors that operate independently of external lighting and the time of day, allowing day/night/all-weather operation.

On the system side, recent advances in low cost RF-CMOS technology have significantly lowered the cost of MMW systems, and enabled the commercialization of these systems such as automotive radars. Building on low power RF-CMOS technology, low cost single-chip collision avoidance radars at 77 GHz have become widely available. Besides offering high range resolution, they also include multiple transmitters and receivers in a single-chip form factor that can be electronically configured into coherent beam forming mode for MIMO (multiple-input, multiple-output) radar mode with enhanced angular resolution. MMW radars operating in MIMO mode are particularly attractive for tracking UASs.

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A reliable UAS radar system must be able to discriminate quadcopters, fixed-wing drones, from birds and slow-moving ground objects. Micro-Doppler is generated due to the organic motion of the various components within a target, such as propeller blade rotation for a drone or wing flapping for a bird. Because these motions result in distinct time-Doppler-frequency patterns, micro-Doppler is more useful than RCS or bulk speed for unique identification of small UAS targets. Higher frequencies at MMW band could be advantageous by providing better Doppler resolution from ground clutter in a shorter time, therefore reducing the minimum detectable target velocity. When combined with artificial neural networks or other machine learning algorithms, these micro-Doppler features can be used to train a radar to detect and classify an UAS.

Despite the potential advantages of MMW radar for counter UAS detection, many challenges exist in hardware and software. Hardware at MMW frequencies remains expensive and low efficiency, resulting bulky systems with high power consumption. Fully utilization of micro-Doppler features will require development in low phase-noise sources as well as classification algorithms that can operate with limited training data. The goal of this STTR topic is overcoming these challenges to achieve systems with both high spatial resolution and classification performance using micro-Doppler extracted from MMW MIMO radar returns.

PHASE I: Establish a MMW MIMO radar simulation testbed for detection, classification and tracking of small UASs. Determine system architecture and radar system parameters. Determine radar system hardware specifications and perform trade study between system size, architecture, operating frequency, antenna structure, range, power consumption, etc. Perform design of a prototype radar based on optimized parameters selected from the trade study. Initiate development of signal processing algorithms for the prototype radar. Machine learning techniques are encouraged for processing micro-Doppler signatures for identification and classification of UAS targets. The prototype radar design should demonstrate detection ranges up to 500 m, altitudes between from 10 to 200 ft., and radial speeds between 2 – 10 m/s, and demonstrate simulated classification accuracy > 90% for discrimination of small UAS versus birds, pedestrians, and road vehicles.

PHASE II: Improve prototype radar design developed in Phase I and build a hardware prototype based on the improved design to realize a low power MMW MIMO radar testbed for detection, classification, and tracking of small UASs in complex terrain. Integrate radar system hardware, signal processing software, and user display to demonstrate small UAS detection at ranges up to 1 km, altitudes between 10 and 400 ft., and radial speeds between 2 – 30 m/s in government-defined complex terrain. Establish training data requirements to achieve classification accuracy > 95% for discrimination of small UAS versus birds, pedestrians, and road vehicles. Identify promising approaches to extend detection ranges up to 3 km in potential Phase III research.

PHASE III DUAL USE APPLICATIONS: A low-cost, small-size MMW MIMO radar for detection, classification and tracking of UASs in highly cluttered environments will fill a critical technology gap for the Army. Phase III commercialization of the compact MMW radar developed in this STTR project, if successful, will provide an effective tool for developing strategies for countering potential hostile UAS threats. Phase III efforts will include ruggedizing the radar package and further capability enhancements such as extending detection ranges.

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Similarly, the MMW radars can be used for detecting and classify intruding UASs for civilian applications.

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KEYWORDS: RADAR, MIMO, micro-Doppler, millimeter-wave, unmanned aerial systems (UASs)

VERSION 3

A21C-T010 TITLE: Improved Technology to Treat Drug-Resistant Bacterial Infections

RT&L FOCUS AREA(S): Biotechnology

TECHNOLOGY AREA(S): Bio Medical

OBJECTIVE: Develop a breakthrough technology for treating bacterial infections, particularly those associated with multidrug resistant (MDR) pathogens.

DESCRIPTION: Bacterial infections are particularly significant for military personnel in situations where there may be a long delay between the injury and treatment at a hospital or clinic. The requirement is for a technology that is readily available in far-forward situations and effective against the ESKAPE pathogens (Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter species). Of these, Acinetobacter baumannii has been reported among veterans and soldiers who served in Iraq and Afghanistan and has been referred to as "Iraqibacter." [1] These organisms are the leading cause of nosocomial infections throughout the world. The proposed solution should be safe for users and ideally minimize the potential for organisms to develop resistance. This system could be applied as a bandage or a skin/wound surface treatment to minimize the probability of bacterial infections. Beyond the urgent military need, there is a significant public health requirement for improved antimicrobial wound treatments: there are currently 6.5 million people in the U.S. with chronic wounds or wounds that are slow to heal, according to the U.S. National Institutes of Health [2].

A particularly promising route to a novel antibacterial effective against MDR pathogens is antimicrobial photodynamic therapy (aPDT), also referred to as photodynamic inactivation (PDI). In this process a dye is activated by a light source and interacts with oxygen to produce reactive oxygen species (ROS) with an antimicrobial effect [3, 4, 5, 6]. While many antimicrobial technologies have been investigated, the photodynamic approach has the unique advantage of applying a separate energy source to aid the antimicrobial activity. The ROS are effective against a broad spectrum of species, and this mode of action helps to prevent pathogens from developing resistance. The proposer should identify an effective, portable light source and show how it could be used in far-forward situations. The light-activated approach is potentially limited due to the absorption of light by tissue, and the selected wavelength of light can greatly affect depth of penetration; any response should also address the efficacy against deep wounds.

PHASE I: In Phase I the contractor should develop the selected photodynamic system and show through in vitro tests that it is effective against MDR pathogens under the expected conditions. Tests should compare its performance to currently used antibacterial agents and demonstrate a significant and potentially clinically valuable improvement in performance. The target system should demonstrate antibacterial performance against one or more of the target organisms that is at least as good as the current alternatives. A desirable feature of a novel antibacterial system is a mode of action that will slow development of resistance in pathogenic organisms. The performer should identify methods to apply this treatment in both military hospitals and far-forward situations, and estimate the size, weight and cost of the new system.

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*RESEARCH INVOLVING ANIMAL OR HUMAN SUBJECTS:

The SBIR/STTR Programs discourage offerors from proposing to conduct Human or Animal Subject Research during Phase 1 due to the significant lead time required to prepare the documentation and obtain approval, which will delay the Phase 1 award.

All research involving human subjects (to include use of human biological specimens and human data) and animals, shall comply with the applicable federal and state laws and agency policy/guidelines for human subject and animal protection.

Research involving the use of human subjects may not begin until the U.S. Army Medical Research and Materiel Command's Office of Research Protections, Human Research Protections Office (HRPO) approves the protocol. Written approval to begin research or subcontract for the use of human subjects under the applicable protocol proposed for an award will be issued from the U.S. Army Medical Research and Materiel Command, HRPO, under separate letter to the Contractor.

Non-compliance with any provision may result in withholding of funds and or the termination of the award.

PHASE II: In Phase II the performer will optimize the new photodynamic system. The breakthrough advantage should be clearly identified. For example, is the new system effective against a particular pathogen or category of pathogens? What is the best method of application? What improvement does the new technology provide over existing systems? Does the new technology provide evidence of user safety? In vitro tests will guide development to a photodynamic formulation and bandage pad composition that is effective against multidrug resistant pathogens of concern. During Phase II the performer should define the final product that will be the focus of further testing and FDA clearance, for example by a 510(k) submission demonstrating safety and efficacy. If the performer chooses to test with animal models, all tests must be in compliance with Institutional Animal Care and Use Committee (IACUC) and Animal Care and Use Review Office (ACURO) guidelines.

The final product configuration will be thoroughly evaluated, providing data relevant to both efficacy and ease of use in logistically changing environments. At the conclusion of Phase II the performer will have clearly defined a path to FDA clearance.

PHASE III DUAL USE APPLICATIONS: Phase III work is typically oriented towards technology transition to Acquisition Programs of Record and/or commercialization of SBIR research or technology. In Phase III, the performer is expected to seek funding from non-SBIR government sources and/or the private sector to develop or transition the prototype into a viable product or service for sale in the military or private sector markets. The Phase III description must include the "vision" or "end-state" of the research. It must describe one or more specific Phase III military applications and/or supported S&T or acquisition program as well as the most likely path for transition of the SBIR from research to operational capability. Additionally, the Phase III section must include (a) one or more potential commercial applications OR (b) one or more commercial technology that could be potentially inserted into defense systems as a result of this particular SBIR project. For this topic, both military and non-military medical markets should be considered. The Military Infectious Diseases Research Program (MIDRP), which protects the U.S. military against naturally occurring infectious diseases, could support additional R&D. This subject is also in the mission space of the Bacterial Diseases branch at Walter Reed Army Institute of Research, which has identified multidrug resistant bacteria as one of the top ten most significant infectious disease threats to U.S. Service Members. In addition to military medical research teams, there are multiple organizations that may be sources of funding for development beyond Phase II, including the Biomedical Advanced Research and Development Authority (BARDA, in HHS) and the Combating Antibiotic-Resistant Bacteria Biopharmaceutical Accelerator (CARB-X; https://carb-x.org/about/overview/), “a global non-profit partnership dedicated to accelerating antibacterial research to tackle the global rising threat of drug-resistant bacteria.”

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KEYWORDS: Bacterial infection, multidrug resistant, MDR, ESKAPE pathogen, antibacterial, wound healing

VERSION 3

A21C-T011 TITLE: Solid Oxide Fuel Cell Stacks with Enhanced Power Density

RT&L FOCUS AREA(S): Directed Energy

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Develop a lightweight Solid Oxide Fuel Cell stack with high power density that is also capable of rapid start up times and high cycle life.

DESCRIPTION: In austere environments, power and energy are critical to mission success. A Solid Oxide Fuel Cell (SOFC) has the potential to provide this power from a wide variety of fuels including complex hydrocarbons. However, there is an opportunity to significantly reduce the stack power density and drive down system volume. Currently, 1kW and greater solid oxide stacks are large often with power densities less than 500 W per liter. Research to increase power density is needed to address this limitation. A small lightweight 1 to 3kW solid oxide fuel cell system is desired for a multitude of missions ranging from dismounted solider power to silent watch applications. This technology could be used in a variety of roles including: direct power to Army systems or to charge lithium-ion rechargeable batteries which would significantly reduce the logistical burden (weight and volume) for dismounted soldiers by reducing the number of batteries required for extended mission time as well as for a myriad of civilian electronics applications.

PHASE I: Design, construct, and evaluate component and subscale demonstrators. These results should support the potential to develop a system capable of less than 40 minute start times, greater than 2000 W per liter power density, and cyclic durability in excess of 100 cycles. Provide a detailed conceptual design of a 1-3 kW power system based upon the results generated in these efforts.

PHASE II: In phase II, based on the results from the successful phase I program, design, construct, and evaluate a 1-3kW brass-board Solid Oxide Power System exceeding 3000 W per liter with a start time below 30 minutes. Demonstrate capability to power cycle in excess of 100 times. Deliver brass-board unit to the Army for evaluation. Assess cost and manufacturability of demonstrated technology.

PHASE III DUAL USE APPLICATIONS: Robust SOFC power systems with high power densities will significantly impact both military and commercial applications, accelerating product development, particularly for lightweight portable power devices. Because the market and the number of devices in the commercial sector is much larger than the military market, widespread usage of this technology will drive down the cost of devices for the military. Demonstrate Solid Oxide Power System under field conditions in order to assess applicability to various mission profiles. Demonstrate compatibility with JP-8. Likely sources of funding if the phase III program if successful include: C5ISR, PEO Soldier and PEO Combat Support and Combat Service Support Product Manager Mobile Electric Power Systems.

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KEYWORDS: SOFC, Fuel Cell, Power Density

VERSION 3

A21C-T012 TITLE: Nondestructive Concrete Characterization System

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop a small, portable, low power field device that can estimate the strength and thickness, to 6 feet, of reinforced concrete structures and identify and locate metal contained therein.

DESCRIPTION: Reinforced concrete structures impede the movement of military personnel in a variety of military missions. Non-destructive evaluation (NDE) of the structural characteristics (e.g., material strength, level of reinforcement, thickness) of these structures is important for calculating the amount of charge that must be placed to breach the structure. NDE remains an application requirement in order for missions to remain stealthy. Several techniques have been considered for NDE of reinforced concrete in order to test for defects and deterioration. Techniques such as ultrasound require a transmitter probe that presents short duration high voltage pulses into piezoelectric crystals, and their expansion produces a pressure pulse that administers a broadband field into the concrete. Such systems can be large, require significant power, and are expensive, rendering them impracticable for tactical applications. Conversely, ground penetrating radar is another NDE technique that has also been used extensively to interrogate concrete that may overcome these deficiencies. Currently there are no methods when combined and simple to use to close this need for breaching.

While concrete can withstand significant compressive stresses, its tensile strength is approximately an order of magnitude smaller than the compressive strength. Historically, this issue has been addressed by reinforcing concrete with reinforcing bars, rebar, and/or fibers to improve tensile strength. Recent advances in manufacturing high strength concrete mixes, such as those by Lafarge, have rendered current approaches to assessing strength and thickness of concrete (and thus charge size) less accurate. A simple, low power, small and accurate alternative utilizing ground penetrating radar (GPR) technology is sought. GPR has commonly been used for interrogating the ground in a nondestructive fashion in order to assess the presence of objects of interest (landmines, pipes, IEDs) buried below the surface. There are several geophysical companies who utilize GPR for a variety of interrogation applications, including locating rebar in concrete to aid excavation, location of utilities and pipes, forensics and graveyard surveying, etc. The proposed concept for structural assessment of reinforced concrete must operate in a variety of conditions with high accuracy and rapid analysis time. Systems that leverage currently fielded Army systems are preferred, and a detailed proof of concept plan is critical.

PHASE I: Develop the hardware and software design that supports the interrogation technology needed to estimate relevant structural parameters such as reinforced concrete thickness—up to six feet, concrete strength over a range of 3,000 to 30,000 psi, density of reinforcement, and presence of fiber reinforcement. In addition, the approach should be able to locate metal substructure. The approach should demonstrate the ability to estimate these parameters in controlled proof-of-concept experiments with an accuracy of one foot in thickness and +/- 3,000 psi in strength over a variety of structures. In addition, the impact of reinforcement additives such as composite or metallic fiber should be assessed and design issues to address any confounding issues should be put forth. Power consumption and estimated system weight must also be addressed and should be within a factor of two of similar Army deployed equipment. The existence of metal objects should be detected and located to =/- one foot on the wall surface and the density of reinforcement and fiber-reinforcement estimated.

PHASE II: Develop and field test the proposed system for estimating relevant structural parameters and metal substructure. Optimize the design and algorithms for performance, weight, and power consumption. Develop and engineer hardware and software to meet program goals. Conduct field-testing to validate performance on a variety of representative structures to assess accuracy, time-of-measurement, and identify potential operational limitations of the final hardware. Preference should be given to extending the capability of already deployed Army systems to support multiple functions.

PHASE III DUAL USE APPLICATIONS: Describe the "vision" or "end-state" of the research. Include one or more specific Phase III military applications and/or supported S&T or acquisition program as well as the most likely path for transition of the SBIR from research to operational capability. Additionally, the Phase III section must include (a) one or more potential commercial applications OR (b) one or more commercial technology that could be potentially inserted into defense systems as a result of this particular SBIR project. The proposed technology has potential use in numerous applications within the Department of Defense and the commercial sector. The technology could be used for the Department of Homeland Security as well as state and local authorities, and potentially HAZMAT response teams.

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KEYWORDS: Ground Penetrating Radar, Concrete Characterization, IED Detection, Mine Detection

VERSION 3

A21C-T013 TITLE: Novel Cable Fault Detector, Locator, Classifier, and Predictor

RT&L FOCUS AREA(S): Artificial Intelligence/Machine Learning, Control and Communications, General Warfighting Requirements

TECHNOLOGY AREA(S): Weapons, Electronics, Air Platform

OBJECTIVE: Develop a novel Frequency Modulated Continuous Wave (FMCW) (RADAR) hand-held device with wire as the wave guide approach detecting, locating, classifying, and predicting electrical cables faults.

DESCRIPTION: BACKGROUND: The US Army is currently developing a Frequency Modulated Continuous Wave (FMCW) [RADAR technology] hand-held architecture and tool for detection and localization of simple faults in multi conductor cables. Those simple faults include open and short circuits and deterioration such as corrosion. However, the current FMCW tool is not intended to be capable of predicting future faults.

This STTR should 1) complement and capitalize on; and, 2) be distinct from the current FMCW tool. Complementary – this STTR shall complement the current FMCW by employing current FMCW work and architecture, while extending that architecture framework to enable statistical analysis of cables of different types and sizes. Distinct – this STTR shall be distinct from the current FMCW tool by predicting future faults in cables and analyzing complex types of cable degradation to allow for Prognostic and Predictive Maintenance (PPMx) capabilities.

PROBLEM: The current standard operating procedures for cable fault detection and diagnosis are unable to detect, locate, and classify intermittent faults and corrosion in electrical wiring and connectors. They require invasive techniques to access, remove and/or disassemble the weapon system under test and analysis, and requires significant power and test equipment for this limited task. Many types of faults are hard to identify and replicate using these procedures and equipment, which leads to frequent “No-Fault-Found” test results in weapons system cable bundles (e.g., radar, intermediate missile, and aircraft).

EFFORT: The goal is to capitalize and extend existing efforts and to develop test set consisting of a low power handheld unit suitable for one-person operation, displays measurement results for viewing by its operator, and records and preserves data for transmission and/or download to maintenance facility computers. The unit must be ruggedized for Army fielded operations in its final prototype form. This STTR shall focus on the development of advanced software techniques and data analytics/machine learning (ML) algorithms to predict and recognize wire deterioration, determine what faults may occur, and determine remaining useful life.

DELIVERABLES: Written reports, initial and final designs/schematics, prototypes, demonstrations, control software, prediction algorithms, expected system quality parameters (probability of detection [POD], level of confidence), and, transition and commercialization plans.

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PHASE I: EXPECTATIONS: (1) Conduct research and develop, (2) report in a white paper, (3) evaluating the use of FMCW signal processing as the primary analysis tool in comparison with alternative radar processes. Identify, craft, and develop initial algorithms, and conduct a simple laboratory demonstration, focused initially on the case of a single wire-pair cable and progressing, as time permits, to more complex wire configurations and cable assemblies.

FEASIBILITY: The whitepaper must demonstrate the potential benefits and the shortfalls of research findings, including power, frequency, and signal-to-noise ratios for success, as well as, a novel approach to detection of potential failures, particularly those that could result from kinks, fractures, breaks, and corrosion. Evaluate the potential of analysis based on FMCW radar measurements to predict life expectancy in multi-conductor cables.

RESULTS: (1) A white paper capturing all efforts, (2) an initial laboratory design schematics, (3) a demonstration of results; (4) preliminary control software and prediction algorithms; (5) discussion of expected system quality parameters (probability of detection [POD], level of confidence) that will affect the fault detection, characterization and prediction device during Phase II; and, (6) technical and commercial feasibility analysis. FMWC technology is shareable with academics in the STTR effort with appropriate Non-Disclosure Agreements (NDAs), as needed, to protect Intellectual Property. FMCW is a very well known technology for terrestrial imaging, and all aspects of fine tuning the FMCW RADAR for maximum SNR to include "no noise" wave guides. However, FMCW has not been investigated for wire fault detection where the wave guide (the wire) is potentially very noisy.

PHASE II: EXPECTATIONS: Specify and develop a hand-held engineering prototype with software algorithms to be evaluated within a controlled environment to detect actual and potential cable failures. Conduct detailed investigations into the capabilities and limitations of the prototype design, to include empirical effects of equipment operating frequency, cable frequency response, wire size, and insulation properties. Perform data analysis on multiple cables of different conductor types and numbers of conductors to determine the variability of measurement results as functions of the cable characteristics.

DELIVERABLES: (1) A hand-held prototype demonstrating various fault detection with high POD and high level of confidence (as expected of tactical military equipment), (2) a report documenting all Phase II activities to include but limited to, new research findings, software builds in executable and raw uncompiled form in a common programming language, and preliminary transition and commercialization plans.

PHASE III DUAL USE APPLICATIONS: VISION: Work with PEO Aviation Ground Systems and PEO Missiles and Space to identify both peculiar common and specific system requirements for inclusion in a fully engineered ruggedized prototype to address commercial and military safety, health and human factors concerns, as well as perform information assurance (IA) and software qualification testing to be able to operate within the Army digital environment and validate the system functionality for Army rotor craft and/or ground weapon programs of record. The Program Management Offices would be ready to procure limited production units for first article environmental and field operational testing proving its readiness for fielding. Provide training for the user based community to include user manuals and functional guides. Successful technology development and transition would benefit the electrical and communication industry as a whole providing the private sector with a tool to perform expedient fault isolation on multi conductor cables.

Other potential applications include other DOD departments with multi-conductor cables, other USG Agencies, commercial industries such as aviation, telecom, automotive, and other automated systems using single or multi-conductor cables.

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KEYWORDS: 1) Frequency Modulated Continuous Wave (FMCW) RADAR, 2) Fault Diagnosis, 3) Prognostics, 4) Cable Characteristics, 5) Data Analytics, 6) Machine Learning (ML), 7) Radio Frequency (RF) Transmission Lines, (8) Wave Guide analysis, (9) Artificial Intelligence (AI)

VERSION 3

A21C-T014 TITLE: Reduced Latency and Power Requirements in Automatic Targeting Algorithms using Meta-optic Elements

RT&L FOCUS AREA(S): Artificial Intelligence/Machine Learning, Microelectronics, Autonomy, Hypersonics

TECHNOLOGY AREA(S): Sensors, Materials, Electronics

OBJECTIVE: Investigate and develop meta-optic elements that perform mathematical transformations to reduce latency and power requirements using artificial intelligence algorithms for autonomous target recognition.

DESCRIPTION: Computer vision-aided Autonomous Target Recognition (ATR) is an important DoD modernization priority that helps extend and enhance human capabilities. Current technologies employ advanced artificial intelligence and machine learning (ML) algorithms for feature generation and object classification. In pursuit of increased accuracy, state-of-the-art models have become increasingly complex, thereby introducing latency into the system. For many applications, some degree of latency is acceptable. However, there is an emerging set of operations where latency reduction is paramount as the decision-making process is currently too slow for autonomous systems to respond appropriately. This is especially true when dealing with complex environments and extremely fast-moving objects such as hypersonic vehicles.

One solution for reducing latency is to offload some of the mathematical operations from the processor to the optics. For example, optical analog computation can be used to perform Fourier filtering for image contour detection. This operation produces an image directly on the focal plane that is composed only of contours, effectively performing an image differentiation calculation at the speed of light without any computational expense. In general, optical analog computation performs pre-processing steps that compress the image data and enable ML model solutions with fewer coefficients and lower latency compared with models used on raw data.

One drawback of conventional optical analog systems is that they require bulky lenses and large volumes that are not suitable for SWAP-constrained platforms. A promising option to replace conventional optical elements and reduce SWAP is to employ ultra-thin meta-optic devices. Meta-optics, in contrast to bulky refractive optics, produce customized optical functions using subwavelength scatterers that provide abrupt spatially varying phase shifts. By engineering the geometry and arrangement of scatterers, meta-optics can be designed to perform complex mathematical transforms on the incoming light. When applied to ATR algorithms, these meta-optic operators could provide orders of magnitude reduction in latency while maintaining low size, weight, and power requirements for ATR platforms.

In this program, the Army seeks to partner with a small business and university participant to investigate and develop meta-optic elements for optical analog computation. These elements will perform the computationally expensive operations of ATR algorithms, leading to significantly reduced latency and power requirements. Results from this effort would support a number of DoD programs and general performance objectives for the optical element include low SWAP, large bandwidth, low f-number, and high efficiency.

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PHASE I: Design a thin (<1mm) meta-optic device operating in the infrared (MWIR or LWIR) that performs a spatial differentiation operation. Use modeling and analysis to understand the tradeoffs of key meta-optic parameters, which include but may not be limited to bandwidth, field of view, polarization, speed, and efficiency. Fabricate a preliminary meta-optic device and perform imaging experiments to demonstrate feasibility of the design concept, and show a viable path to meeting Army program requirements.

PHASE II: Explore more complex meta-optic architectures using innovative design methodologies such as inverse design. Develop a meta-optic device that is paired with a computational algorithm for an advanced prototype demonstration. Demonstrate path to manufacturing meta-optics at production quantities. Deliver advanced prototype to Army customer for further testing and evaluation.

PHASE III DUAL USE APPLICATIONS: Design and manufacture meta-optics applicable to specific Army programs. Transition technology to commercial markets where faster artificial intelligence algorithms as well as lower weight and power are important. Some examples include autonomous vehicles, biotechnology, security, and agriculture.

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KEYWORDS: Meta-optics, Optical analog computation, Artificial intelligence, Flat optics

VERSION 3

A21C-T015 TITLE: Photon Counting in the Near-Infrared Band

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platform, Human Systems, Materials, Sensors, Space Platform, Battlespace, Ground Sea

OBJECTIVE: Develop extremely sensitive complementary metal-oxide-semiconductor (CMOS) compatible focal plane array (FPA) technology for imaging in the near-infrared (NIR) band.

DESCRIPTION: Current image intensifier (I2) goggle technology for man-portable applications is bulky in size and weight, and does not lend itself to being fused with other solid state sensors, such as shortwave infrared (SWIR), midwave infrared (MWIR) and/or longwave infrared (LWIR). Conventional silicon charge coupled devices (CCDs) and CMOS imagers have not demonstrated passive low light imaging capabilities under heavy overcast starlight levels (approx. 1x10-6 fL).

For passive low light level imaging, the signal must be maximized and noise minimized. This topic seeks to develop extremely sensitive CMOS compatible FPAs capable of detecting a signal in the NIR in heavy overcast starlight conditions. To achieve performance comparable to Gen III I2 goggle technology, the solid state technology must be capable of high gain with low excess noise (high signal to noise ratio), high quantum efficiency, and low dark current at ambient temperatures. Solutions should optimize the quantum efficiency (QE) in the NIR from 0.7-1.0µm. NIR imagers that are sensitive beyond 1.0µm (into the SWIR) are encouraged. Size, weight, and power (SWaP) should be taken into account in the final imager solution. Novel device architectures are encouraged; uncooled devices are preferred.

PHASE I: Design a sensor optimized to operate in the NIR spectral region, from 0.7-1.0µm, that is capable of detecting a signal in low light conditions, down to approx. 1x10-6 fL. Deliver a preliminary design that demonstrates technical feasibility through design, modeling, and analysis. A kick-off meeting should be held with the Government; monthly progress reports and a final report at the end of Phase I should be submitted.

PHASE II: Produce the sensor solution designed in Phase I and integrate it into a prototype imager system, taking into account SWaP. Imagers should be useable in the field (i.e., there should be a means to keep out dust, moisture, etc.), but need not to be ruggedized. Technical reviews should be held with the Government; monthly progress reports and a final report at the end of Phase II should be submitted. Deliver the prototype imager system to the Government, and be available to support at least one field event to observe low light imaging performance.

PHASE III DUAL USE APPLICATIONS: Refine imager developed in Phase II into a ruggedized package for military and/or commercial applications. Military applications can include Soldier worn or weapon mounted systems, as well as small autonomous platforms, such as unmanned ground or air vehicles. Nonmilitary commercialization opportunities would include security and surveillance applications.

VERSION 3

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KEYWORDS: NIR, infrared, imaging, camera, low light, photon counting

VERSION 3

A21C-T016 TITLE: Future Solid-State and Ionic Liquid, High Voltage Electrolytes for Elevated Energy Density Batteries

RT&L FOCUS AREA(S): Control and Communications, Space

TECHNOLOGY AREA(S): Air Platform, Electronics, 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: Develop solid state and/or ionic liquid electrolytes that promote safe operation at high voltage and enable superior gravimetric energy density (Wh/kg) when incorporated into high voltage lithium-ion batteries.

DESCRIPTION: Solid-state (SSE) and ionic liquid (IL) electrolytes are promising technologies for incorporation into future generations of LIBs. These forthcoming electrolytes can accommodate greater electrochemical stability with increasing voltage, empowering safe engagement of high voltage materials. Development of battery cells with high operating voltage will augment energy and power densities of future lithium-ion batteries, as expressed by Ohm's law. Increased energy densities will prolongate battery run times or permit smaller batteries capable of comparable mission profiles, minimizing battery weight. Emphasis on these research areas is being proposed now due to the development, which we now know can achieve 5V cell voltages, leading to an opportunity to further enhance the military battery portfolio. Cells of higher operating voltages will also allow simultaneous utilization of electronics, benefitting large platform integration. Successful improvement of SSE and IL at high voltages would assist U.S. Army modernization priorities of Soldier Lethality, Future Vertical Lift, Next Generation Combat Vehicle, and Long Range Precision Fires.

Incumbent LIBs fail to assuage the safety requirements for future soldier and vehicle platforms. Solid-state (inorganic solids, composites, polymers, etc.) and ionic liquid electrolytes exhibit improved safety compared to standard carbonate electrolytes due to amelioration of flammability and electrochemical stability issues when paired with lithium-metal anodes. Solid-state electrolytes, have potential to suppress detrimental lithium dendrite formation and provide desired mechanical and thermal stability. Safe electrolytes that enable safe operation with lithium metal anodes at high voltages will forge energy density improvements of 200-250%.

Challenges to implementation include charge transfer impedance at the electrode-electrolyte interface that must be mitigated to promote rapid and reversible charge transfer. A feasible solution is the development of an artificial SEI layer to promote accelerated ion diffusion. Polymer electrolytes may exhibit poor adhesion to the solid electrode causing reduced electrolytic penetration into the electrodes, which proliferates resistance. Adding liquid electrolytes to counteract this process is effective but eliminates the safety advantages of the solid electrolytes and is not considered as a solution for this proposal.

Additional hindrances for successful utilization of these electrolytes are ionic conductivities of electrolytes at room temperature and below. Electrolyte ionic conductivity is affected by temperature dependence of the viscosity of ionic liquids. The Army requires dependable operation of energy storage devices between -30°C and +55°C. Therefore, enhancing the ionic conductivity of these electrolytes for low temperature operation through use of additives or improved overall design is an additional research objective.

Design goals for the resultant cells are listed below. Carbonate electrolytes will not be considered. Proposed improvements to high internal resistances and poor ionic conductivity, and strategy for enabling high voltage operation must be expressed in full detail. Cells must:

- Contain lithium-metal anode
- Contain solid-state (inorganic solids, composites, polymers, etc.), ionic liquid electrolytes, or safe electrolytes
- Operate at high voltage with complete discharge redox behavior occurring above 4.6V
- >100 cycles with >80% capacity retention
- Cell energy densities > 350 Wh/kg at room temperature
- >75% capacity retention at 0 °C with respect to room temperature capacity

PHASE I: Design a concept cell for solid state or ionic liquid electrolyte that optimizes gravimetric energy density (>350 Wh/kg) at elevated discharge voltages (with complete discharge redox behavior occurring above 4.6V) and prolonged cycle life above 80% capacity retention. Carbonate electrolytes will not be considered. 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 coin or pouch cells to meet target performance requirements of high voltage operation with complete discharge redox behavior occurring above 4.6V, >350 Wh/kg (cell), 100 cycles > 80% capacity retention 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 (coin or pouch), as well as monthly progress reports and a final report.

PHASE III DUAL USE APPLICATIONS: Transition this technology to prototype cells of suitable size for packaging and assembly into batteries for soldier carried applications and, upon further testing, inclusion in future Army vehicles such as Future Vertical Lift and Next Generation Combat Vehicle. The product for phase III is multilayered pouch cells with capacities > 2 Ah to be included in future batteries.

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KEYWORDS: Energy Storage, Polymer Electrolytes, Ionic Liquid electrolytes, High Energy Density, Improved Safety, Soldier Lethality, Future Vertical Lift

VERSION 3

A21C-T017 TITLE: Low Earth Orbit Positioning, Navigation and Timing (LEO-PNT)

RT&L FOCUS AREA(S): Space, Control and Communications

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop and demonstrate a hardware/software approach for Positioning, Navigation and Timing (PNT) using Low Earth Orbiting (LEO) satellites as a component in the context of the PNT Operating System (pntOS).

DESCRIPTION: The near term expansion of internet service to include commercial broadband low earth orbiting (LEO) satellites provides a potential for robust PNT, using their waveforms as Signals of Opportunity (SOOP).

Unlike Global Navigation Satellite Systems (GNSS), such as GPS, which has an infrastructure to maintain very precise time throughout the constellation, and satellites with specially designed transmitters, clocks, and a waveform dedicated to the PNT function, SOOPs by their nature are in space for another purpose and not optimized for PNT. Therefore, the challenge for this topic is to exploit features of the SOOP waveforms designing innovative techniques in order to establish range to satellites and henceforth provide the user with the dismount/platform's position and current time (desired).

The technology developed under this topic will result in an approach for LEO-PNT that is intended for dismounted Soldiers and Mounted vehicular applications, but may have further applications to aerial, munition and missile applications. The design will use a software defined receiver approach and be capable of incorporation as a component in the context of the Army's pntOS program enabling maximum application. This technology although designed to work standalone can be used to complement existing navigation sensors that are typically used in navigation systems, including GPS. Expansion to the usage of multiple constellations will serve to optimize performance and resiliency in an RF challenged environment. LEO satellites closer proximity to Earth and signal structures can allow for higher signal powers to reach the end user. Investigations conducted under this topic will include technical design approaches that will improve PNT performance (position and timing (desired) accuracy) and also the ability to operate in RF challenged environments such as dense urban, mountainous, forested and jungle environments. It's recognized that many implementations of SOOPs use reference stations in surveyed/fixed based locations. For most Army applications reference stations are undesirable due to the logistics burdening associated with manning the station, redeploying it as the unit maneuvers from location to location, emplacement/survey of the station to support operations and the required command and control for the system. A goal of this program is to develop a LEO PNT SOOP technical approach that will not require a reference station. However, cooperative PNT methods that share information using networks sharing information between unit platforms/members is encouraged. However, caution is required not to over burden the network. Metrics that will be assessed include position and time (desired) accuracy, availability of service (analyzed across the earth), bandwidth usage of a network, Size, Weight and Power (SWAP), complexity associated with system initialization and overall set up time.

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PHASE I: Develop a design for the LEO-PNT system architecture. Determine requirements and conduct a hardware and software functional allocation for the system. The intended system at a minimum will be relevant to operations for dismounted Soldiers and Mounted. Develop system error budgets supporting the performance metrics, providing allocations to the various elements of the system design, transmission medium, local environment, and selected SOOPs, for supporting operations for the intended applications. Conduct necessary trade studies and modeling and simulation that will contribute to the architecture definition, determine feasibility and reduce risk in Phase II. The primary product of Phase I will be a system specification for LEO PNT and how it can be integrated with existing navigation systems.

PHASE II: Design and build a system prototype that is capable of supporting demonstrations by dismounted Soldiers and in Mounted as a “plug n play” capability for incorporation within the Army pntOS. The initial prototype may be scaled in terms of capacity (numbers of compatible LEO SOOP constellations, minimum for Phase II will be 2), but it should be proven that full scale operation is feasible with the resulting design. Use cases to be demonstrated are dismounted Soldier and Mounted, proving sufficient PNT capability in open range, forested/jungle, and urban. Metrics mention in the Description will be evaluated.

PHASE III DUAL USE APPLICATIONS: This topic has the potential to scale and continue to grow and support the entire Army (perhaps DOD) PNT ecosystem. Continued development and refinement of the system will be further expanded in terms of compatibility with additional SOOP constellations, and improvements made through cooperative sharing of information. This capability could easily be accommodated to a commercial capability supporting non-military functions, for virtually an unlimited number of applications.

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KEYWORDS: Positioning, Navigation and Timing (PNT), Assured Positioning, Navigation and Timing (APNT), Low Earth Orbiting (LEO), Army PNT Operating System (pntOS), Signals of Opportunity (SOOP)

VERSION 3

A21C-T018 TITLE: Ultra-Wide and High-Average Power Directional IR Countermeasures

RT&L FOCUS AREA(S): Directed Energy

TECHNOLOGY AREA(S): Electronics, Sensors, Air Platform

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 an ultra-broadband IR source for countermeasures capable of disrupting and/or disabling optical/IR guiding sensors in targets.

DESCRIPTION: For directional IR countermeasures (IRCM) applications, generating high-average power, pulsed IR radiation with an ultra broad and uniform spectrum is highly desirable. The IR atmospheric transmission window of interest is in the range of ~8 – 13 um, i.e. long-wave IR (LWIR) and ~2 – 5 um, mid-wave IR (MWIR). In these spectral regimes, the IR radiation can be generated at the source and propagated to the target to disrupt its optical/IR sensors. However, there is a lack of suitable high-power sources in the MWIR and LWIR.

High-average power, ultra-broad band radiation in this spectral regime can be generated by the spectral broadening and/or nonlinear parametric amplification of laser radiation in an appropriate nonlinear, lossless, material. Ultra-broad band radiation is generated from a laser pulse by a number of coupled highly nonlinear optical processes that include: i) self-phase modulation, ii) 4-wave mixing, iii) cross-phase modulation, iv) stimulated Raman scattering, and others. These mechanisms can lead to wide spectral broadening around the fundamental and other frequencies that may cover the MWIR and LWIR regimes with high overall conversion efficiencies. In addition, the IR radiation could have a high degree of directionality and thus can be propagated long distances within a small solid angle using an appropriate beam director.

This topic seeks solutions that eliminate threats through the disruption of a target's optical control systems rather than destroying the target by thermal disruption mechanisms. Novel laser configurations, such as laser pulse formats and bandwidth manipulations that would generate ultra-broadband MWIR and LWIR radiation are of interest. The pump (source) lasers that generate the wideband radiation should be compact, reliable and commercially available. Proposed systems should be capable of disrupting IR sensors within the engagement time window, at tactically relevant ranges.

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PHASE I: The offeror will theoretically/computationally and experimentally demonstrate the feasibility of remotely disrupting or disabling optical/IR sensors representative of those found in military targets at relevant ranges (greater than 1 km). By "disruption", it is meant that the device sensors are temporarily disrupted or permanently disabled so that the target cannot perform its mission. Theoretical studies and/or modeling to understand the phenomenon employed and/or beam director design characteristics as appropriate to the proposed solution should be included.

The deliverable for Phase I will be the design of a system that will be constructed and tested in Phase II.

PHASE II: The offeror will construct and deliver a system that can apply broad band, high average power, directional IR radiation on a remote target such that the target's optical/IR sensors are disrupted or permanently disabled. No specific target is necessary for a proposal to be of interest, however it must be demonstrated that the technique can be applied to targets of military relevance. A system with a capability of disrupting or disabling military targets beyond 1 km is desired. A plan for scaling the capability to longer ranges is also highly desirable. The offeror should also demonstrate - through theory, modeling or experiment – the extent to which the system may disrupt or disable targets greater than 1 km away.

The deliverable for Phase II will be a functional prototype of the system design proposed in Phase I. The prototype will be utilized to gather test data and generate a test report demonstrating the application to optical/IR sensors.

PHASE III DUAL USE APPLICATIONS: The offeror will outfit the DE countermeasures system with subsystems to identify, acquire, track, and defeat targets. The overall system must be rugged and mobile. The offeror will demo the system in a field test in an operationally relevant environment. Field tests are to be carried out using various types of targets representative of those employed in the military at tactically relevant ranges greater than 1 km.

The deliverable for Phase III will be the functional prototype developed in Phase II integrated with acquisition/tracking subsystem. The integrated system will be utilized to gather test data and generate a test report demonstrating application to optical/IR sensors at relevant range.

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KEYWORDS: IRCM, laser, IR, infrared, broad, wide

VERSION 3

A21C-T019 TITLE: Bispectral Obscurant for Artillery Application

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): 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 compressible bi-spectral (0.4 – 12 microns) obscurant material for artillery applications.

DESCRIPTION: Smoke and obscurants play a crucial role in protecting the Warfighter by decreasing the electromagnetic signature that is detectable by various sensors, seekers, trackers, optical enhancement devices and the human eye. Recent advances in materials science now enable the production of precisely engineered obscurants with nanometer level control over particle size and shape. Numerical modeling and many measured results on semiconducting and conducting microfibers affirm that more than order of magnitude increases over current performance levels are possible if these microfibers can be effectively disseminated as an un-agglomerated aerosol cloud. Research to discover a single material or a combination of materials that covers the bispectral portion of the EMS spectrum that exhibits very high performance per unit mass will enable bispectral obscuration for artillery and mortars. This advancement will expand the capability of the Army to project screens that defeat EO/IR threat sensors.

PHASE I: Demonstrate with samples a material(s) with an extinction of at least 10 m2/gm across the wavelength region from 0.4 to 12 microns. (5) 1 g samples shall be provided to CBC for evaluation. Material should be selected to be robust enough to weather high compression forces and still perform at the desired level. Phase I will focus identifying the candidate material with an extinction of at least 10 m2/gm. Phase II will demonstrate the ability condense and redisperse the obscurant and the ability for the material to survive the high G forces (30,000) that it will be subjected to upon launch.

PHASE II: Demonstrate that the material can be densified to 50% of theoretical maximum and that aerosolization of the sample results in at least 50% single particles. Demonstrate that the fabrication of the obscurant material is scalable by providing 4 1-kg samples with no loss in performance from that achieved with the small samples. In addition, in Phase II, a design of a manufacturing process to commercialize the manufacture of materials should be developed.

PHASE III DUAL USE APPLICATIONS: The techniques developed in this program can be integrated into current and future military obscurant applications. Improved artillery and mortar rounds 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: Bispectral, infrared, high performance, packing, aerosolization, obscuration

VERSION 3

A21C-T020 TITLE: Modeling and Design Tool for Bio-Based Construction Products

RT&L FOCUS AREA(S): General Warfighting Requirements, Biotechnology

TECHNOLOGY AREA(S): Materials

OBJECTIVE: Develop a structural design that has energy considerations for bio-based construction products including cross-laminated and mass timber as well as hybrid systems with polymer matrix composites.

DESCRIPTION: This topic focuses the development of design tools for sustainable bio-based construction products for potential use in military construction applications. An increased focus on climate change has led the way for alternative construction materials. In particular, timber products, such as cross-laminated timber (CLT) and mass timber, have been increasing utilized. Wood production requires less energy than either steel or concrete, and contains sequestered CO2, lowering a building's cradle-to-grave environmental impact [1]. It is also faster to construct in comparison to both steel and concrete, such that a well-designed timber project can have economic benefits as well as environmental ones. For example, the tallest timber structure in North America –the Brock Commons at the University of British Columbia, standing 18 stories tall and consisting of mass timber framing with a concrete core was erected in 70 days (four months shorter than typical buildings of this size). Furthermore, its carbon footprint reduction is in excess of 2,000 metric tons compared to similar concrete and steel structures [2]. In response to priorities in climate change mitigation and improved resilience of military construction, the Army requires new technologies that will better enable the design and construction of facilities utilizing sustainable construction products in a similar fashion as historical trends in military construction using steel and concrete.

PHASE I: Demonstrate modeling and design tools focused initially during Phase 1 on blast response to typical anti-terrorism force protection threats / level of protection requirements focused on comparisons between typical construction approaches (CMU walls, concrete, etc.) vs. the use of bio-based building products such as CLT, mass timber, and hybrid systems. This may require limited experimentation, but it is anticipated that prior testing [3,4] can be leveraged to support this requirement. The design approach should be implemented in a preliminary tool, either software or spreadsheet based, for blast response. This design tool is not required to be fully validated or capable during Phase 1, but rather a conceptual demonstration of the tool for further development in Phase 2. Deliver a report documenting the initial research activities under Phase 1 to document the initial concept.

PHASE II: Advance design tools to consider additional factors not studied in Phase 1 including additional design configurations and loading conditions for force protection applications. Phase 2 should also consider other structural design considerations as well as energy efficiency / thermal properties of bio-based systems compared with conventional construction approaches. Design approaches should be validated using large scale experimentation / demonstrations. Design approaches and modeling tools should be delivered in simple software tools that are likely tied to production level computational tools (e.g., structural / finite element analysis computational tools) or modifications to existing approaches for structural design.

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Deliver a reporting document that includes a description a description of the final design tools, the research and demonstration / validation results of all studies performed, and proposed directions for integration into military construction criteria, guidance, and specifications.

PHASE III DUAL USE APPLICATIONS: The work has a broad range of applications for military construction as well as civilian applications for sustainable infrastructure. The studies conducted under Phase 1 and 2 will be novel and useful across a range of civilian and military applications. And we anticipate that, outside of unique force protection capabilities, the developed tools would have broad applicability and freedom for dissemination for civilian applications.

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1. C. Hill and K. Zimmer, "The Environmental Impacts of Wood Compared to Other Build-ing Materials," Norsk Institutt for Bioøkonomi, 2018;
2. P. Fast, "Case Study: An 18-storey tall mass timber hybrid student residence at the Uni-versity of British Columbia," in Internationales Holzbau-Forum IHF, 2016;
3. C. Senalik, "Blast-Resistant Testing for Loaded Mass Timber Structures," U.S. Forest Product Laboratory, 2018;
4. M. K. Weaver, C. M. Newberry, L. Podesto and C. O'Laughlin, "Blast Testing of Loaded Cross-Laminated Timber Structures," in Structural Congress , 2018

KEYWORDS: Blast, Force Protection, Energy, Modeling, Structural, Engineering, Materials, Building, Facilities, Wood, Timber, Sustainable, Construction

VERSION 3

A21C-T021 TITLE: Online and Offline Terrain Strength Estimation Using Remote Sensing for Ground Vehicle Mobility Planning

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop methods to remotely acquire terrain strength data using infrared (IR) sensors that results in increased vehicle safety, mobility, and maneuverability compared to current approaches to off-road navigation.

DESCRIPTION: The Army modernization priority identifies the autonomous maneuverability and off-road mobility of platforms as a critical research area [1]. Robust online remote terrain strength estimation is essential for autonomous ground vehicle mobility over off-road deformable terrains while offline remote terrain strength estimation enables route planning.

In order to maximize performance in off-road settings, mobility planning needs to account for the interaction between the vehicle running gear and terrain surface. The most widely used models for force prediction on deformable terrains are the semi-empirical models based on Bekker's classical terramechanics theory [2]. These terramechanics models require inputs of terrain strength properties that vary spatially and temporally. Current methods to acquire these inputs rely on in-situ or satellite-based geographic information systems (GIS) data. Terrain strength data gathered in the theatre of operation may be of high quality and resolution but is resource intensive in terms of manpower and time, making it potentially infeasible for large areas of operation. On the other hand, satellite-based terrain data may be available for large geographic regions, however, these sources often lack the capacity and resolution required to make accurate mobility predictions of terrain strength at the vehicle level [3]. Further, both methods fail to provide means of updating a priori terrain strength data during field operations, resulting in poor vehicle mobility if terrain properties have changed due to seasonal effects, weather impacts, natural disasters, and even human adversarial activity.

A novel method to obtain terrain strength relies on remote sensing using IR sensors placed on a ground vehicle or a UAV. Several benefits of this approach include the ability to collect data at vehicle-level resolution, quickly gather terrain strength information over large areas of operation, and automate the transmission and processing of sensor readings to be used during offline route planning before an operation or online mobility planning within an autonomous control system of the ground vehicle in real time. Recent studies have shown success in using hyperspectral and thermal remote sensing in estimating soil type and soil strength [4]. However, fundamental research questions need to be addressed to advance remote sensing for autonomous ground vehicle off-road mobility. These questions/topics include:

-Relating remote sensor measurements such as hyperspectral and thermal images to terrain mechanical properties such as cohesion, friction, bearing, and cone index.
-Scalability of the technology from small terrain area to large operational region.
-Efficiency of the technology to produce data for online navigation of autonomous vehicles in faster than real time.

-Robustness of the technology to operate successfully under varying weather and ground conditions as well as measurement uncertainty.
-How to integrate the remotely sensed terrain strength parameters into the running gear force prediction models for autonomous ground vehicle systems towards online and offline path planning?
-Quantitatively evaluate the benefit of integrating remotely sensed terrain strength parameters for autonomous path planning and validate the results.
-Evaluate the robustness of the remotely sensed terrain strength parameters under varying terrain conditions and different soil types.

PHASE I: Identify the components required to develop remote sensing capabilities for offline mobility planning. Offline planning entails collecting terrain data over a large area such that a Go/No-Go map can be generated prior to conducting a military operation in that region. Required components may include the test vehicle, potential UAV, IR sensors, and terramechanics models to predict vehicle-terrain interaction using inferred terrain mechanical properties from remote sensing. Conduct initial integration of the components to demonstrate feasibility. The deliverable will be proof-of-concept field demonstration using physical hardware integrated with software to showcase the application of remote terrain sensing to ground vehicle mobility predictions in deformable terrain under off-road conditions. The demonstration output shall be able to support a short vehicle traversal (<0.5 km) with nearly real time terrain information (within 24 hours of sensing terrain).

PHASE II: This phase would build upon the foundational efforts of Phase I. Extensive field testing across multiple soil types, varying environmental conditions such as increased moisture, and over large scale geometry will be conducted to evaluate the robustness of the approach, and if needed, employ methods to mitigate uncertainty in terrain strength estimations. Another task will be to update the remote sensing capability from an offline only implementation to online, meaning terrain strength will be remotely sensed and transmitted to an autonomous vehicle's control algorithm to inform its path planner that uses terramechanics soil models in real time or faster. Note that online remote terrain sensing shall be performed by having the sensors mounted on the autonomous ground vehicle itself. Also, mobility trials with and without remotely sensed terrain strength estimations will be conducted in order to quantify its impact on off-road performance. The deliverable will be a prototype autonomous vehicle with remote sensing capability through IR sensors that augment the path planner's decision making with terrain strength data in real time to improve mobility performance demonstrated across a wide range of military relevant conditions.

PHASE III DUAL USE APPLICATIONS: Work in Phase III would focus on collaborating with Army personnel to transition the developed methodology to the Army. Both optionally manned and unmanned vehicles aligned with the Next Generation Combat Vehicle (NGCV) program, as well as robotic and bridging programs within Project Manager Force Projection of Program Executive Office Combat Support and Combat Service Support, would directly benefit whether they use terrain data remotely sensed offline before an operation or online during a mission in conjunction with the autonomous control system. The technology would be tested to evaluate its accuracy and robustness, and to demonstrate its effectiveness to Army stakeholders. Furthermore in this phase, the technology can be extended to include sharing of sensed terrain data across multiple platforms (V2X communication).

This technology would also provide commercial sectors the capability of enhanced off-road mobility. The mining industry is moving towards automated vehicles for their promise of increased safety and productivity [5] with similar trends observed in the agriculture sector for increased yields [6]. In addition, as space exploration becomes more privatized, companies would look towards advanced terrain navigation technologies to ensure the success of planetary missions [7].

REFERENCES:
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2. Laughery, Sean C. et al. “Bekker's Terramechanics Model for Off-Road Vehicle Research.” (1990);
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4. Ewing, Jordan, et al. "Utilizing Hyperspectral Remote Sensing for Soil Gradation." Remote Sensing 12.20 (2020): 3312;
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KEYWORDS: Infrared, sensing, autonomy, terramechanics, mobility, off-road, real time, unmanned ground vehicles

VERSION 3

A21C-T022 TITLE: Cybersecurity Capability for the neXtECU Engine Controller

RT&L FOCUS AREA(S): Cybersecurity

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Implement and maintain, cybersecurity protocols for the GVPM-RTCS neXtECU engine controller. This capability needs to meet current and future cybersecurity requirements for all ground vehicle programs.

DESCRIPTION: Current Engine Control Units (ECUs) being used in military vehicles, such as the Honeywell's Digital Engine Control Unit (DECU) used in Abrams M1A2 Tanks, are becoming un-supportable and obsolete. The neXtECU, is a viable drop-in replacement controller option for the Abrams M1A2 along with other vehicle platforms such as the 1790 M88 Hercules. It is also currently used to support the development of the Advanced Combat Engine (ACE) and Powertrain (APD) upgrades. The advantages of the neXtECU are not only that it can be implemented on multiple vehicle platforms, but that it will also provide protection for the data it sends and stores. It is essential to adapt and implement cybersecurity protocols into the neXtECU for Army ground vehicles because of the exponential growth of technology and an increased rate of cyber-attacks by U.S. adversaries both foreign and domestic. Currently fielded engine controllers have limited to no cybersecurity protection which leaves them open for Malware, phishing, and possibly clandestine equipment. Without the increased cybersecurity technologies on the engine controller a vehicle can be manipulated by threats in a variety of different ways such as: interrupted flow of data, unauthorized commands to critical components which can endanger human life, and is a danger to critical and costly equipment. Compromised equipment can also lead to drastic increases in life-cycle costs, and can potentially negatively affect overall mission capabilities and success. The cybersecurity measures developed for the neXtECU will effectively protect, restrict, and encrypt data, protocols, and communication systems. The technological solution to be developed will be required to integrate a Hardware Security Module (HSM) with a 5777m processor into the neXtECU. This solution will propose possible interfaces between the bootloader, ECU, and application software. The proposed solution shall also have the potential to secure all communication buses. The proposed Microcontroller Unit (MCU) solution shall possess and industry proven trusted key store concept. Furthermore, the MCU shall address production key updates in field, and an initial strategy for generating and securing keys. These updated technologies will provide users with a safe and secure operating system that provides real-time data and information using an encrypted and protected operating system. The cybersecurity technology will also enable the neXtECU's system integrity by keeping information from being altered which provides confidence that the system information is confidential, protected, and un-corrupted. The neXtECU has many benefits for the Army due to its wide application for all ground vehicles, and it can provide a solution to upcoming sustainment issues, cybersecurity, and capability enhancements. This neXtECU with the proposed cybersecurity technology can also be used in the automotive industry, with autonomous driving vehicles, over-the-air vehicle software updates, wireless device linking, and for many other cyber based advancements that are presently growing.

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PHASE I: Identify and determine the software, hardware, and other technologies/equipment needed to develop this cybersecurity technology concept to work with the neXtECU. The proposed solution shall not require a hardware re-design of the neXtECU. An integration and compatibility study should be conducted in this phase to be used in Phase II to interface the new technologies within the neXtECU. An investigation of solutions shall be compatible not only with the neXtECU, but other potential industry Microcontroller Units (MCU's). Techniques and methods developed in this phase should meet all government cybersecurity provided requirements, as well as any other requirements developed during this phase. While developing requirements, this phase should evaluate overall key performance parameters needed to be successful to meet Phase II requirements. A competitive analysis and proposal of all potential embedded systems for security (i.e. ESCRYPT, Argus, Trillium, Karamba, etc.) or similar shall be conducted. A breakdown of all potential solutions as well as their commercial merit and their feasibility is required. Finally a bill of materials, volumes, and part costs for Phase I and Phase II designs should also be developed and outlined for the proposed solution. Designs in this phase also need to address any challenges identified in the above description or set of requirements.

PHASE II: Phase II will develop and integrate the prototype software and hardware into the neXtECU based on the Phase I designs and solutions that were developed and recommended. The cybersecurity technology shall be designed to support all current development protocols for the neXtECU's programming (ETAS XETK, CAN UDS, Lauterbach, etc.). During this phase bench testing demonstrations will be required to accurately gauge and establish performance parameters. The expectation will be to have the GVSC Cybersecurity team test the final design to assess the capability to secure software re-programming, secure communications, and to demonstrate overall integration into the neXtECU. Phase II efforts will finalize the requirements, overall system protections and system functionality. A final bill of materials, production costs, volumes, all developed software, and a prototype shall be deliverables for the Phase II design.

PHASE III DUAL USE APPLICATIONS: During this phase the solution for the neXtECU's cybersecurity technologies will be implemented. Additionally, integration of the neXtECU into the 1790 M88 Hercules vehicle platforms will take place during Phase III.

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KEYWORDS: neXtECU, Cybersecurity, Controller, Platforms, Protocols, Technology, Capabilities

VERSION 3

A21C-T023 TITLE: Large Scale Metal Additive Manufacturing Process for Army Components

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): 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 find an additive manufacturing process/method to produce large scale components for military systems that have repeatable material properties, using a physics-based approach.

DESCRIPTION: Additive manufacturing (AM) is currently and will continue to be a major area of interest for the Army moving forward. This is for a variety of reasons, including sustainment (printing obsolete or difficult to acquire parts, part repair), readiness (eliminating long lead times), light-weighting (geometry optimization), and more. The Army, more so than most other industries, has the need to additively manufacture large scale metallic components. There are several AM methods that can be used for this (powder bed, electron beam, WAAM, cold spray, etc.), but none that are widely accepted (within the Army) to producing large scale (larger than 1 m2 in the x-y plane) production parts.

GVSC Materials Directorate wishes to partner through the STTR program to further characterize large scale metal AM parts and work toward certification of the parts and the AM process/method used to manufacture them. Successful applicants must have commercially available AM technology (one AM method) that can print steel, aluminum, and/or titanium alloys, and meets a minimum build size of 1 square meter (in the x-y plane). Applicants must also have a planned or currently available in-situ process/technology that uses a physics-based approach to ensure repeatability and statistical confidence of material properties of the parts produced, regardless of the part geometry. Awardees will partner with a research entity which will test printed material in two phases. The intent of Phase I is for each awardee to use a different, large scale AM method. Phase I will consist of material characterization testing that will include, at a minimum; tensile properties, hardness distribution, impact toughness (Charpy v-notch or as-appropriate), microstructural analysis, void fraction, and fatigue. After Phase I, the awardees/AM methods will be down-selected to the one (or two) that show the most promising results and move forward into Phase II. Phase II will consist of refining the physics-based process to increase, as much as possible, the repeatability of material properties of parts with differing geometries. Material characterization testing will continue by taking samples directly from printed parts (vehicle components), which are identified by the government. The effort in

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Phase II is to increase the baseline properties identified in the first set of tests, resulting in a process and parts that meet Army weapon systems requirements. The final deliverables will be one or more prototype parts that can be used for on-vehicle testing, and a physics-based record showing the repeatability of the specific AM process.

PHASE I: Phase I is intended for each awardee to use a different, large scale AM method (powder bed, electron beam, WAAM, cold spray, etc.). Phase I will determine the AM method(s)/process(es) that have the greatest feasibility to produce repeatable and statistically confident material properties of large scale metallic parts. Phase I will consist of material characterization testing that will include, at a minimum; tensile properties, hardness distribution, impact toughness (Charpy v-notch or as-appropriate), microstructural analysis, void fraction, and fatigue.

PHASE II: Phase II awards will be made to firms on the basis of results of their Phase I effort and potential to transition to Phase III. Phase II will consist of refining the physics-based process to increase, as much as possible, the repeatability of material properties of parts with differing geometries. Material characterization testing will continue by taking samples directly from printed parts, which are identified by the government. The effort in Phase II is to increase the baseline properties identified in the first set of tests, resulting in a process and parts that meet Army weapon systems requirements. The final deliverable will be one or more prototype parts that can be used for on-vehicle testing.

PHASE III DUAL USE APPLICATIONS: Phase III will end with a commercially available Additive Manufacturing method, with a physics-based control process, that is capable of printing large scale metallic components with reliable and repeatable material properties. The technology can be used to produce large components for Army vehicles such as structural components, chassis components, large turret components, large hatches, etc. It will also be useful for other industries, such as aerospace, large truck/trailer, and others.

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KEYWORDS: additive manufacturing, big metal, electron beam, EBAM, wire arc, WAAM, cold spray, powder bed, physics-based control, in-situ control process, sustainment, readiness, lightweighting

VERSION 3

A21C-T024 TITLE: Non-invasive device for prevention or treatment of Acute Stress Reaction

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Bio Medical

OBJECTIVE: Develop a non-invasive device that either 1) prevents functional impairment due to an Acute Stress Reaction (ASR) or 2) returns Soldier to performance following the occurrence an ASR.

DESCRIPTION: Mental health symptoms stemming from severe stress exposure during deployment degrade performance and compromise the safety of Soldiers and their teams in far forward operational environments. In 2018, 28% of medical evacuations were attributed to mental health-related symptoms (Armed Forces Health Surveillance Branch, 2018). Anticipated conditions of the future battlefield will increase the cognitive demands on Soldiers, and it is expected that the incidence of severe stress exposures, and thus mental health symptoms, will escalate. Soldiers will be operating in small teams for prolonged periods without ready access to tactical or medical support due to communication-interfering capabilities of adversaries and other limitations of the operational environment. These conditions will increase exposure to severely stressful situations, prolong the amount of time Soldiers must cope with severe stress reactions, and magnify the opportunity for decrements in performance to put personal safety and the mission at risk. Therefore, it might be expected that the incidence of ASR will increase. An ASR is a normal response to a severe physical or mental stressor, such as combat, that results in maladaptive emotional, cognitive, somatic, and/or behavioral symptoms during the first 1-3 days following a traumatic event. Unfortunately, there are currently no FDA-approved treatments for ASR. Further, existing treatments for trauma-related disorders such as PTSD have limited efficacy in Soldiers and take 4-6 weeks to reach effects. It is therefore critical to develop safe and effective interventions to support Soldier performance prior to, during, and after severe stress exposure during combat operations. Additionally, treatments for ASR should not result in significant cognitive, motor or other functional side effects, act rapidly to sustain Soldier performance, and be safely administered in operational environments as part of pre-hospital care. This STTR aims to develop a non-invasive device that could be used in training prior to, during, or immediately following a traumatic stress exposure to maintain Soldier performance in an operational environment. The deliverable must function in a range of environments (e.g., laboratory, operational training, in garrison, and far forward deployment settings) where smartphone usage, service, and internet availability is variable. In the context of multi-domain operations, internet, electronic, or blue tooth connectivity will not be likely.

PHASE I: Phase I will focus on development of performance parameters and initial concept testing for a prototype device. Performer should develop a plan for a practical deployment, use of the prototype in different environments (e.g., in lab, in garrison, training, deployed settings) where there is variable access to electronic or internet connectivity. Primary performance parameters to be considered for devices that will be utilized as preventative treatments include level of efficacy in maintaining baseline performance, preventing the occurrence of stress-related symptoms, training time needed, ease of use, retention time of treatment effects, impact on functional performance, portability, maintenance requirements and network requirements. Performance parameters to be considered for devices that will be utilized as pre-hospital treatments include level of efficacy in restoring performance and/or reducing stress-related symptoms, time to reach treatment effects, FDA market authorization (if applicable), ease of use, retention time of treatment effects, impact on functional performance, portability, maintenance requirements, network requirements, production costs, and maintenance costs. Finally, this phase will produce a virtual or in-person demonstration of device function based on established performance parameters.

PHASE II: Phase II will focus on creating a field-testable prototype that meets the criteria determined in Phase I. The aim will be to demonstrate proof-of-concept by developing, testing, and refining a prototype. In order to accomplish this Phase II testing and evaluation, the objectives for human subject research for testing and data acquisition must be defined. A research protocol aimed at validating the prototype in a laboratory setting should evaluate the capabilities of the prototype through limited human testing in laboratory research. The laboratory testing should demonstrate that the device is able to 1) effectively prevent decrements in performance on operationally relevant tasks or increased stress symptoms following training and stressor administration in a laboratory setting or 2) effectively restore performance on operationally relevant tasks or stress symptoms following stressor administration in a laboratory setting. During this phase, the stressor administration does not need to be a traumatic stressor, but can utilize a well-validated model of human laboratory stress. The stress and measures of performance should be as operationally relevant and translatable to military stress and operational performance as are feasible. A regulatory strategy should be put in place if applicable, including a pre-submission meeting with the FDA to assist with protocol design.

PHASE III DUAL USE APPLICATIONS: Phase III will focus on refinement of the device prototype, based on evaluation data obtained in Phase II, in order to create a final production-ready system. The full functionality of this final device will be evaluated within an operational field environment. For devices that will be utilized as preventative treatments, effectiveness will be evaluated using baseline performance metrics gathered prior to training with the device and an appropriate comparison group may be determined based on device specifications and with input from the FDA. For devices that will be utilized as pre-hospital treatments, effectiveness will be evaluated using an appropriate comparator based on the device specifications and with input from the FDA, as appropriate. The vision for this capability is to have a device that can be used during pre-deployment training to prevent an ASR or for pre-hospital treatment of ASRs during combat. Defense R&D funding may be obtained in coordination with an advanced developer, such as US Army Medical and Materiel Development Activity (USAMMDA) Warfighter Brain Health Project Management Office, to expedite the technology transition from the laboratory to operational use. As applicable, the company will develop a quality management system and regulatory strategy for FDA marketing application submission. This effort will deliver a product that is broadly usable by the DoD for prevention or treatment of ASR. The final product should be presented to applicable DoD representatives and program managers for transition to use in military environments. Further, the utility of this a non-invasive device may be relevant to industry, academia, and the general public for the potential treatment of other trauma-related disorders, pending additional FDA marketing authorizations. Awardees must outline a commercialization pathway including, but not limited to, regulatory strategy, marketing strategy, consumer feedback, and sales.

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KEYWORDS: Traumatic stress, neuromodulation, neurofeedback, acute stress reaction, acute stress disorder

VERSION 3

A21C-T025 TITLE: Novel High Performance Oriented Films for Ballistic Protection

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): 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: Develop new oriented film based materials with superior ballistic performance, good durability, manufacturability, and cost competitive to currently fielded ballistic fibers and fabrics.

DESCRIPTION: In recent years, advances in polymer processing science and technology have enabled the development of highly oriented polymer films with mechanical properties that significantly exceed previous materials made with the same base polymer. Advances have been made in producing and drawing films from difficult-to-process polymers with exceptional properties, such as ultrahigh molecular weight polyethylene. These materials have already advanced the state of protective soldier protective systems, such as with the development of the advanced combat Helmet Gen II.1 In addition to achieving preferential orientation of base polymers, researchers have demonstrated formation of nanocomposite films with exceptional properties. Optimization of film processing parameters can be greatly aided by laboratory techniques that allow better fundamental understanding of the structural evolution of polymer films during post-stretching processing; recent advances in synchrotron radiation (SR) light sources and detection techniques allow measurement of the polymer's changing morphology in real time with the use of a combination of small- and wide-angle X-ray scattering (SAXS/WAXS). These studies can be used to create process-structure-property databases that can be used as the basis for model discovery and combined with artificial intelligence techniques to rapidly converge on optimal processing conditions, rather than using traditional trial and error techniques.2

There are compelling indications that oriented films may provide superior ballistic performance to oriented fibers made of the same polymer. Around 2007, several manufacturers began producing a solid state extruded film made from ultrahigh molecular weight polyethylene. The ballistic performance of this film was noted to be higher than expected given its low tensile strength relative to its ultrahigh molecular weight polyethylene fiber counterpart (3,4). Oriented films such as uniaxially oriented polypropylene have also shown promise for transparent armor.5 The technical challenge of meeting optical transmittance and clarity requirements for transparent armor while providing a high level of ballistic protection is much more significant than for opaque armor. Thus, transparent oriented films with improved ballistic performance are of particular interest in this topic.

PHASE I: Phase I of the program should demonstrate feasibility of the technical approach and development of the initial material concept. Offerer will select materials for candidate films and explore processing mechanisms for creating oriented films with superior properties. Materials can include base polymers as well as additives. The focus of Phase I is to demonstrate the ability to enhance the properties of the base polymer film through processing and use of additives. Measurements to characterize the film material’s morphology and correlate it to processing conditions and to mechanical properties should be performed in Phase 1.
Technologies will be evaluated for transition to Phase II based on improved tensile strength and modulus values. U* may also be used to evaluate performance advancement. 6

PHASE II: Phase II should focus on material production to generate prototypes for ballistic evaluation. The PI will develop materials and processes to fabricate ballistic flat panels at areal densities from about 0.5 pounds per square foot (psf) up to about 1.0 psf. At a minimum, materials for opaque armor should be tested for V50 against 17 grain fragment simulating projectile (FSP). Transparent materials should be tested for transmissivity, haze, scratch resistance, and V50 against 17 grain and 5.8 grain fsp (0.125 inch thich samples). Final deliverables should include a cost estimate for scale up and production of the material, technical data package, prototypes for evaluation by the Government and a final report.

PHASE III DUAL USE APPLICATIONS: Phase III should focus on scale up of the material product and building prototype components to demonstrate appropriate applications of the material. For opaque armor, prototype components could include helmets and/or ceramic plate armor backings. Lenses or visors should be the focus for transparent material applications. While the animus for this topic is improved ballistic protection at the dismounted soldier level, the technology may be extrapolated for broader military use. Improved materials may also be of commercial interest for non-DoD protective and security services.

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KEYWORDS: Ballistic materials, oriented polymer films, nanocomposites, transparent armor, ballistic eyewear

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A21C-T026 TITLE: Thermally Functional UAV Coating

RT&L FOCUS AREA(S): Autonomy, Biotechnology, General Warfighting Requirements

TECHNOLOGY AREA(S): 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: Research and develop an innovative, low ESOH risk coating for infrared (IR) and thermal management of a UAV. Demonstrate this IR-functional coating on a UAV in a relevant environment.

DESCRIPTION: In multi-domain operations, Unmanned Aerial Vehicles (UAV) widely operate as an extension of the Warfighter and squad, enabling much better situational awareness. UAVs are also used commercially for transporting loads, monitoring networks, and many other civilian applications. More widespread infrared (IR) imaging capabilities among adversaries means that it is increasingly easy to identify UAVs during operation, reducing their effectiveness and compromising the mission. Due to both increased use of UAVs and increased access to IR imaging capabilities by adversaries, there is a strong and emerging need for coatings to protect UAVs from detection by reducing the expected maximum range to image. However, many of the available coatings that could protect the UAVs from detection, especially in the IR/ visible (optical) ranges, contain materials that are toxic and bad for the environment; e.g., isocyanates.

Nature has enabled sophisticated color schemes in the animal kingdom, including bright and dark tones for camouflage. Bio-inspired materials have been extensively researched in the academia, and bio-inspired coatings fabricated with the ability to mask signature, and even regulate temperature, as Nature does. Simultaneously, bio-inspired materials and biomaterials are being explored in synthetic biology, enabling US manufacturing to be simpler, more environmentally friendly, use less toxic materials, and be less dependent on rare materials imported from few foreign nations. The DoD and Army must bring more environmentally friendly and less toxic materials into its supply chain, and is required to make surface coating products and processes that are more Environment, Safety, and Occupational Health (ESOH) sustainable.

The goal of this topic is to develop an innovative coating with infrared functionality – managing both signature and thermal properties/temperature – for a small UAV that accompanies the Warfighter and is capable of reconnaissance missions. “Infrared functionality” includes passive (and active, i.e. actuated heat release port, etc) temperature control. Emissions must be controlled in the longwave IR (LWIR) or thermal IR, as specified quantitatively below. While the visible, near-infrared, and short-wave (SWIR) infrared are not a focus of this Topic, a coating that is successful for both military and commercial applications must also manage optical properties (e.g., reflectivity and absorption) in these spectral ranges. Batteries, operating as hot as 60°C, and motors, will contribute hotspots to a UAV's thermal image. UAVs can be observed at distances ~ 100m with IR cameras [1], even when not visually observable. Advanced gimballed, large detection systems could image UAVs at shorter range. Bio-inspired materials, like bio-pigments, exhibit strong IR scattering and high refractive indices, and could strongly affect IR images of a passive coating [2]; these materials have been introduced into fibers. Coatings could be smooth and paint-like, or on fibers and/or textile-like material (i.e. [3]), possibly adding IR functionality, but they must be robust to withstand continuous flights at the rated velocity of the UAV, through different weather conditions. Coatings must have lower ESOH risk than traditional DoD paints, which can no longer contain materials like hexavalent chromium. Polyethylene is an example of one environmentally-interesting material, proposed for thermal and color management [4].

PHASE I: Conduct a feasibility study by identifying, through early stage experiments and modeling (not just modeling), a coating that can be used to trap heat inside a UAV that is conformal, paint-like, and does not have significant ESOH risk for use by operators and manufacturers; for example, a bio-inspired material with backwards infrared scattering centers. Deliver coated samples of representative UAV body elements (wings, battery encasements, motor hubs, etc.) with experimental results demonstrating IR absorption/reflection properties that indicate potential range reduction for LWIR camera-based detection/imaging below 100m. Model potential performance improvements relevant to increased operating temperature for UAV, and possibly LWIR imaging degradation. Model weight of coating for an entire UAV and any effects on aerodynamics of the UAV. Document results of experiments and modelling in a report.

PHASE II: Building on Phase I work, in Year 1 of Phase II: demonstrate a prototype, consisting of a fully coated UAV using a coating with low ESOH risk, and demonstrate in a lab environment the coating's effect on LWIR imaging (using a LWIR camera) of the UAV, degrading images taken at more than 100 m. Also in Year 1, demonstrate improvement to operating temperature range (e.g., any thermal management improvements). In Year 2, include in the prototype a way to mitigate temperature swings of the UAV; e.g., release heat if internal temperature becomes too high; for example, opening a heat exhaust port ("heat valve") at the back of the UAV temporarily to reduce heat load inside the UAV. In Year 2, the 100 m maximum LWIR range must be improved, any leakage of elevated UAV body temperature into the SWIR range considered, and some temperature control demonstrated. Ideally in Year 2, conduct a toxicological assessment of any new materials used in the coating, with Army Public Health Command. Report ESOH impact and weight of the optimized coating, including potential new heat valve, and demonstrate minimal effects on aerodynamics of UAV and plan for mitigating any heat build-up in warmer environments. Demonstrate coating is as resilient to environmental conditions (temperature, humidity, rain, etc) as uncoated UAV body elements, or report on the reduction in operating ranges for these properties, ideally in a relevant environment (the full system must be demonstrated at least in a laboratory environment). Deliver full prototype of coated UAV to the government. Document results of experiments and modelling in reports for both Year 1 and Year 2. Comment in the reports about the tradeoffs of using a low ESOH-risk passive coating vs. active approaches to avoid detection like use of scattering agents in a released gas.

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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 in an operationally relevant environment for the Army. Demonstrate reduced IR signature and improved operating temperature range in this environment. Dual use potential for coating comes in two principle areas (1) its use for IR concealment and (2) its use for thermal regulation. (1) Coated UAVs could be marketed to law enforcement (police, department of homeland security, etc.) for its ability to provide UAV concealment to improve surveillance applications. Licensing to or partnering with existing UAV manufacturers in this commercial space would be ideal. (2) Coated UAVs and coatings could also be marketed to widespread commercial applications (agriculture, delivery services, photography, cinematography, hobbyists) on the basis of improving thermal regulation of the UAV in cold environments. Many users face issues from temperatures being too cold for batteries of flight computers to operate normally, reducing mission and flight times.

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KEYWORDS: Unmanned aerial vehicles (UAVs), Unmanned vehicles (UXVs), Thermal Management, IR Concealment, Bio-pigment Coatings, Bio-manufacturing