ARMY
20.1 Small Business Innovation Research (SBIR)
Proposal Submission Instructions

INTRODUCTION

The U.S. Army Combat Capabilities Development Command (CCDC) is responsible for execution of the Army SBIR Program. Information on the Army SBIR Program can be found at the following Website: https://www.armysbir.army.mil/.

Broad Agency Announcement (BAA), topic, and general questions regarding the SBIR Program should be addressed according to the DOD Program BAA. For technical questions about the topic during the pre-release period, contact the Topic Authors listed for each topic in the BAA. To obtain answers to technical questions during the formal BAA period, visit https://sbir.defensebusiness.org/. Specific questions pertaining to the Army SBIR Program should be submitted to:

Monroe Harden
Acting Program Manager, Army SBIR
usarmy.apg.ccdc.mbx.sbir-program-managers-helpdesk@mail.mil
U.S. Army Combat Capabilities Development Command
6662 Gunner Circle
Aberdeen Proving Ground, MD 21005-1322
TEL: 866-570-7247

The Army participates in three DOD SBIR BAAs each year. Proposals not conforming to the terms of this BAA will not be considered. Only Government personnel will evaluate proposals.

PHASE I PROPOSAL SUBMISSION

SBIR Phase I proposals have four Volumes: Proposal Cover Sheet, Technical Volume, Cost Volume and Company Commercialization Report. **Please note that the Army will not be accepting a Volume Five (Supporting Documents), nor a Volume Six (Fraud, Waste and Abuse) as noted at the DOD SBIR website.** The Technical Volume .pdf document has a 20-page limit including: table of contents, pages intentionally left blank, references, letters of support, appendices, technical portions of subcontract documents (e.g., statements of work and resumes) and any other attachments. Small businesses submitting a Phase I Proposal must use the DOD SBIR electronic proposal submission system (https://www.dodsbirsttr.mil/submissions/). This site contains step-by-step instructions for the preparation and submission of the Proposal Cover Sheet, the Cost Volume, and how to upload the Technical Volume. For general inquiries or problems with proposal electronic submission, contact the DOD SBIR Help Desk at 1-703-214-1333 or DoDSBIRSupport@reisystems.com.

The small business will also need to register at the Army SBIR Small Business website: https://sbir.army.mil/SmallBusiness/ in order to receive information regarding proposal status/debriefings, summary reports, impact/transition stories, and Phase III plans. PLEASE NOTE: If this is your first time submitting an Army SBIR proposal, you will not be able to register your firm at the Army SBIR Small Business website until after all of the proposals have been downloaded and we have transferred your company information to the Army Small Business website. This can take up to one week after the end of the proposal submission period.

Do not include blank pages, duplicate the electronically generated cover pages or put information normally associated with the Technical Volume such as descriptions of capability or intent in other sections of the proposal as these will count toward the 20-page limit.

Only the electronically generated Cover Sheets and Cost Volume are excluded from the 20-page limit. **Army Phase I proposals submitted containing a Technical Volume .pdf document containing over 20 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 20 page limit.**

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

Phase I proposals will be reviewed for overall merit based upon the criteria in Section 6.0 of the DOD Program BAA.

20.1 Phase I Key Dates

BAA closes, proposals due	12 Feb 2020, 8:00 pm ET
Phase I Evaluations	14 Feb 2020 – 30 Apr 2020
Phase I Selections Announced	12 May 2020
Phase I Award Goal	10 Aug 2020*

**Subject to the Congressional Budget process*

PHASE I OPTION MUST BE INCLUDED AS PART OF PHASE I PROPOSAL

The Army implements the use of a Phase I Option that may be exercised to fund interim Phase I activities while a Phase II contract is being negotiated. Only Phase I efforts selected for Phase II awards through the Army's competitive process will be eligible to have the Phase I Option exercised. The Phase I Option, which **must** be included as part of the Phase I proposal, should cover activities over a period of up to four months and describe appropriate initial Phase II activities that may lead to the successful demonstration of a product or technology. The Phase I Option must be included within the 20-page limit for the Phase I proposal. Do not include blank pages, duplicate the electronically generated cover pages or put information normally associated with the Technical Volume such as descriptions of capability or intent, in other sections of the proposal as these will count toward the 20 page limit.

PHASE I COST VOLUME

A firm fixed price or cost plus fixed fee Phase I Cost Volume with maximum dollar amount of **$167,500** must be submitted in detail online. Proposers that participate in this BAA must complete a Phase I Cost Volume not to exceed a maximum dollar amount of **$111,500** for the six months base period and a Phase I Option Cost Volume not to exceed a maximum dollar amount of **$56,000** for the four months option period. The Phase I and Phase I Option costs must be shown separately but may be presented side-by-side in a single Cost Volume. The Cost Volume DOES NOT count toward the 20-page Phase I proposal limitation when submitted via the submission site's on-line form. When submitting the Cost Volume, complete the Cost Volume form on the DOD Submission site, versus submitting it within the body of the uploaded proposal.

PHASE II PROPOSAL SUBMISSION

Only Small Businesses that have been awarded a Phase I contract for a specific topic can submit a Phase II proposal for that topic. Small businesses submitting a Phase II Proposal must use the DOD SBIR electronic proposal submission system (https://www.dodsbirsttr.mil/submissions/)This site contains step-by-step instructions for the preparation and submission of the Proposal Cover Sheet, the Cost Volume, and how to upload the Technical Volume. For general inquiries or problems with proposal electronic submission, contact the DOD Help Desk at 703-214-1333.

Army SBIR has four cycles in each FY for Phase II submission. A single Phase II proposal can be submitted by a Phase I awardee within one, and only one, of four submission cycles and must be submitted between 4 to 17 months after the Phase I contract award date. Any proposals that are not submitted within these four submission cycles and before 4 months or after 17 months from the contract award date will not be evaluated. The submission window opens at 0001hrs (12:01 AM) eastern time on the first day and closes at 2359 hrs (11:59 PM) eastern time on the last day. 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 SBIR PM in advance.

The next available four Phase II submission cycles following the announcement of selections for the 20.1 BAA are:

2021(a) 15 Oct – 13 Nov 2020
2021(b) 1 Mar – 30 Mar 2021
2021(c) 15 Jun - 14 Jul 2021
2021(d) 2 Aug – 31 Aug 2021

For other submission cycles see the schedule below, and always check with the Army SBIR Program Managers Office helpdesk for the exact dates.

SUBMISSION CYCLES	TIMEFRAME
Cycle One	30 calendar days starting on or about 15 October*
Cycle Two	30 calendar days starting on or about 1 March*
Cycle Three	30 calendar days starting on or about 15 June*
Cycle Four	30 calendar days starting on or about 1 August*

*Submission cycles will open on the date listed unless it falls on a weekend or a Federal Holiday. In those cases, it will open on the next available business day.

Army SBIR Phase II Proposals have three Volumes: Proposal Cover Sheet, Technical Volume, and Cost Volume. The Technical Volume .pdf document has a 38-page limit including: table of contents, pages intentionally left blank, references, letters of support, appendices, technical portions of subcontract documents (e.g., statements of work and resumes), data assertions and any attachments. Do not include blank pages, duplicate the electronically generated cover pages or put information normally associated with the Technical Volume in other sections of the proposal as these will count toward the 38 page limit. As with Phase I proposals, it is the proposing firm's responsibility to verify that the Technical Volume .pdf document does not exceed the page limit after upload to the DOD SBIR/STTR Submission site by clicking on the "Verify Technical Volume" icon.

Only the electronically generated Cover Sheet and Cost Volume are excluded from the 38-page Technical Volume.

Army Phase II Proposals submitted containing a Technical Volume .pdf document over 38 pages will be deemed NON-COMPLIANT and will not be evaluated.

Army Phase II Cost Volumes must contain a budget for the entire 24 month Phase II period not to exceed the maximum dollar amount of **$1,100,000.** During contract negotiation, the contracting officer may require a Cost Volume for year one and year two. The proposal cost volumes must be submitted using the Cost Volume format (accessible electronically on the DOD submission site), and may be presented side-by-side on a single Cost Volume Sheet. The total proposed amount should be indicated on the Proposal Cover Sheet as the Proposed Cost. Phase II projects will be evaluated after the first year prior to extending funding for the second year.

Small businesses submitting a proposal are 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.

DOD is not obligated to make any awards under Phase I, II, or III. For specifics regarding the evaluation and award of Phase I or II contracts, please read the DOD Program BAA very carefully. Phase II proposals will be reviewed for overall merit based upon the criteria in Section 8.0 of the BAA.

BIO HAZARD MATERIAL AND RESEARCH INVOLVING ANIMAL OR HUMAN SUBJECTS

Any proposal involving the use of Bio Hazard Materials must identify in the Technical Volume whether the contractor has been certified by the Government to perform Bio Level - I, II or III work.

Companies should plan carefully for research involving animal or human subjects, or requiring access to government resources of any kind. Animal or human research must be based on formal protocols that are reviewed and approved both locally and through the Army's committee process. Resources such as equipment, reagents, samples, data, facilities, troops or recruits, and so forth, must all be arranged carefully. The few months available for a Phase I effort may preclude plans including these elements, unless coordinated before a contract is awarded.

FOREIGN NATIONALS

If the offeror proposes to use a foreign national(s) [any person who is NOT a citizen or national of the United States, a lawful permanent resident, or a protected individual as defined by 8 U.S.C. 1324b (a) (3) – refer to Section 3.5 of this BAA for definitions of "lawful permanent resident" and "protected individual"] as key personnel, they must be clearly identified. **For foreign nationals, you must provide country of origin, the type of visa or work permit under which they are performing and an**

<u>explanation of their anticipated level of involvement on this project. Please ensure no Privacy Act information is included in this submittal.</u>

OZONE CHEMICALS

Class 1 Ozone Depleting Chemicals/Ozone Depleting Substances are prohibited and will not be allowed for use in this procurement without prior Government approval.

CONTRACTOR MANPOWER REPORTING APPLICATION (CMRA)

The Contractor Manpower Reporting Application (CMRA) is a Department of Defense Business Initiative Council (BIC) sponsored program to obtain better visibility of the contractor service workforce. This reporting requirement applies to all Army SBIR contracts.

Offerors are instructed to include an estimate for the cost of complying with CMRA as part of the Cost Volume for Phase I (**$111,500 maximum**), Phase I Option (**$56,000 maximum**), and Phase II (**$1,100,000 maximum**), under "CMRA Compliance" in Other Direct Costs. This is an estimated total cost (if any) that would be incurred to comply with the CMRA requirement. Only proposals that receive an award will be required to deliver CMRA reporting, i.e. if the proposal is selected and an award is made, the contract will include a deliverable for CMRA.

To date, there has been a wide range of estimated costs for CMRA. While most final negotiated costs have been minimal, there appears to be some higher cost estimates that can often be attributed to misunderstanding the requirement. The SBIR Program desires for the Government to pay a fair and reasonable price. This technical analysis is intended to help determine this fair and reasonable price for CMRA as it applies to SBIR contracts.

- The Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) operates and maintains the secure CMRA System. The CMRA Web site is located here: https://www.ecmra.mil/.

- The CMRA requirement consists of the following items, which are located within the contract document, the contractor's existing cost accounting system (i.e. estimated direct labor hours, estimated direct labor dollars), or obtained from the contracting officer representative:

  (1) Contract number, including task and delivery order number;
  (2) Contractor name, address, phone number, e-mail address, identity of contractor employee entering data;
  (3) Estimated direct labor hours (including sub-contractors);
  (4) Estimated direct labor dollars paid this reporting period (including sub-contractors);
  (5) Predominant Federal Service Code (FSC) reflecting services provided by contractor (and separate predominant FSC for each sub-contractor if different);
  (6) Organizational title associated with the Unit Identification Code (UIC) for the Army Requiring Activity (The Army Requiring Activity is responsible for providing the contractor with its UIC for the purposes of reporting this information);
  (7) Locations where contractor and sub-contractors perform the work (specified by zip code in the United States and nearest city, country, when in an overseas location, using standardized nomenclature provided on Web site);

- The reporting period will be the period of performance not to exceed 12 months ending September 30 of each government fiscal year and must be reported by 31 October of each calendar year.

- According to the required CMRA contract language, the contractor may use a direct XML data transfer to the Contractor Manpower Reporting System database server or fill in the fields on the Government Web site. The CMRA Web site also has a no-cost CMRA XML Converter Tool.

Given the small size of our SBIR contracts and companies, it is our opinion that the modification of contractor payroll systems for automatic XML data transfer is not in the best interest of the Government. CMRA is an annual reporting requirement that can be achieved through multiple means to include manual entry, MS Excel spreadsheet development, or use of the free Government XML converter tool. The annual reporting should take less than a few hours annually by an administrative level employee.

Depending on labor rates, we would expect the total annual cost for SBIR companies to not exceed $500.00 annually, or to be included in overhead rates.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA) (FORMERLY KNOWN AS DISCRETIONARY TECHNICAL ASSISTANCE)

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 SBIR projects through a network of scientists and engineers engaged in a wide range of technologies. The objective of this effort is to increase Army SBIR 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.

The Army has stationed nine 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 organizations within their regions.

For more information go to: https://www.armysbir.army.mil, then click the "SBIR" tab, and then click on Transition Assistance/Technical Assistance.

This technical and business assistance to SBIR awardees to assist in:

- Making better technical decisions on SBIR projects
- Solving technical problems that arise during SBIR projects;
- Minimizing technical risks associated with SBIR projects; and
- Developing and commercializing new commercial products and processes resulting from such projects including intellectual property protections.

Army may provide up to $5,000 of SBIR funds for the technical assistance described above for each Phase I award, and $10,000 per Phase II project to these vendors for direct support to SBIR awardees.

Alternatively, an SBIR firm may directly acquire the technical assistance services described above and not through the vendor selected by the Components. Firms must request this authority from the agency and clearly identify the need for assistance (purpose and objective of required assistance), provide details on the provider of the assistance (name and point of contact for performers) and why the proposed TABA providers are uniquely skilled to conduct the work (specific experience in providing the assistance proposed), and the cost of the required assistance (costs and hours proposed or other details on arrangement). This information must be included in the Explanatory Material section of the firm's cost proposal specifically identified as "Discretionary Technical and Business Assistance."

If the awardee demonstrates this requirement sufficiently, the agency shall permit the awardee to acquire such technical assistance itself, in an amount up to $5,000 for each Phase I award and $10,000 for each Phase II project, as an allowable cost of the SBIR award. The per year amount will be in addition to the award and is not subject to any profit or fee by the requesting (SBIR) firm and is inclusive of all indirect rates.

The TABA provider may not be the requesting firm, an affiliate of the requesting firm, an investor of the requesting firm, or a subcontractor or consultant of the requesting firm otherwise required as part of the paid portion of the research effort (e.g. research partner or research institution).

Failure to include the required information in the Phase I and/or Phase II proposal will result in the request for discretionary technical and business assistance being disapproved. Requests for TABA funding outside of the Phase I or Phase II proposal submission will not be considered. If the firm is approved for TABA from a source other than that provided by the agency, the firm may not be eligible for the technical assistance services normally provided by those organizations. Small business concerns that receive technical or business assistance as described in this section are required to submit a description of the assistance provided, and the benefits and results achieved. Contact the Army SBIR Program Office for any other considerations.

NOTE: The Small Business Administration (SBA) is currently developing regulations governing TABA. All regulatory guidance produced by SBA will apply to any SBIR contracts where TABA is utilized.

It should also be noted that if approved for discretionary technical and business assistance from an outside source, the firm will not be eligible for the Army's Technical Assistance Advocate support. 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, and a web site 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 SBIR Program Manager. The maximum TABA dollar amount that can be requested in a Phase I Army SBIR proposal is $5,000. The maximum TABA dollar amount that can be requested in a Phase II Army SBIR proposal is $5,000 per year (for a total of $10,000 for two years).

COMMERCIALIZATION READINESS PROGRAM (CRP)

The objective of the CRP effort is to increase Army SBIR technology transition and commercialization success and accelerate the fielding of capabilities to Soldiers. The CRP: 1) assesses and identifies SBIR projects and companies with high transition potential that meet high priority requirements; 2) matches SBIR companies to customers and facilitates collaboration; 3) facilitates detailed technology transition plans and agreements; 4) makes recommendations for additional funding for select SBIR projects that meet the criteria identified above; and 5) tracks metrics and measures results for the SBIR projects within the CRP.

Based on its assessment of the SBIR project's potential for transition as described above, the Army utilizes a CRP investment fund of SBIR dollars targeted to enhance ongoing Phase II activities with expanded research, development, test and evaluation to accelerate transition and commercialization. The CRP investment fund must be expended according to all applicable SBIR policy on existing Phase II availability of matching funds, proposed transition strategies, and individual contracting arrangements.

NON-PROPRIETARY SUMMARY REPORTS

All award winners must submit a non-proprietary summary report at the end of their Phase I project and any subsequent Phase II project. The summary report is unclassified, non-sensitive and non-proprietary and should include:

- A summation of Phase I results
- A description of the technology being developed
- The anticipated DOD and/or non-DOD customer
- The plan to transition the SBIR developed technology to the customer
- The anticipated applications/benefits for government and/or private sector use
- An image depicting the developed technology

The non-proprietary summary report should not exceed 700 words, and is intended for public viewing on the Army SBIR/STTR Small Business area. This summary report is in addition to the required final technical report and should require minimal work because most of this information is required in the final technical report. The summary report shall be submitted in accordance with the format and instructions posted within the Army SBIR Small Business Portal at:
https://sbir.army.mil/SmallBusiness/ and is due within 30 days of the contract end date.

ARMY SBIR PROGRAM COORDINATORS (PCs) for Army SBIR PHASE 20.1

Participating Organizations	Program Coordinator	Phone
Army Futures Command (AFC)	Casey Perley	716-754-6311
Armaments Center (AC)	Sheila Speroni	973-724-6935
Aviation and Missile Center (AvMC-A)	Dawn Gratz	256-842-3272
Aviation and Missile Center (AvMC-M)	Dawn Gratz	256-842-3272
Army Research Laboratory (ARL)	Francis Rush Nicole Fox	919-549-4347 919-549-4395
Army Test & Evaluation Command (ATEC)	Kendra Raab	443-861-9344
Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR)	Lauren Marzocca	410-395-4665
Chemical Biological Center (CBC)	Martha Weeks	410-436-5391

Engineer Research & Development (ERDC)	Melonise Wills	703-428-6281
Ground Vehicle Systems Center	George Pappageorge	586-282-4915
PEO Aviation	Randy Robinson	256-313-4975
PEO Command, Control and Communications Tactical (PEO C3T)	Meisi Amaral	443-395-6725
PEO Intelligence, Electronic Warfare & Sensors (PEO IEW&S)	Michael Voit	443-861-7851
PEO Missiles & Space	David Tritt	256-313-3431
PEO Soldier	Mary Harwood	703-704-0211
PEO STRI	Robert Forbis	407-384-3884
Space and Missile Defense Command (SMDC)	Jason Calvert	256-955-5630
Soldier Center (SC)	Cathy Polito	508-206-3497

ARMY SUBMISSION OF FINAL TECHNICAL REPORTS

A final technical report is required for each project. Per DFARS clause 252.235-7011 (http://www.acq.osd.mil/dpap/dars/dfars/html/current/252235.htm#252.235-7011), each contractor shall (a) Submit two copies of the approved scientific or technical report delivered under the contract to the Defense Technical Information Center, Attn: DTIC-O, 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218; (b) Include a completed Standard Form 298, Report Documentation Page, with each copy of the report; and (c) For submission of reports in other than paper copy, contact the Defense Technical Information Center or follow the instructions at http://www.dtic.mil.

DEPARTMENT OF THE ARMY PROPOSAL CHECKLIST

This is a Checklist of Army Requirements for your proposal. Please review the checklist to ensure that your proposal meets the Army SBIR requirements. You must also meet the general DOD requirements specified in the BAA. **Failure to meet these requirements will 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 **$111,500** with up to a six-month duration) AND an optional effort (up to **$56,000** for an up to four-month period to provide interim Phase II funding).

2. The proposal is limited to only **ONE** Army BAA topic.

3. The technical content of the proposal, including the Option, includes the items identified in Section 5.4 of the BAA.

4. SBIR Phase I Proposals have three (3) sections: Proposal Cover Sheet, Technical Volume and Cost Volume. The Technical Volume .pdf document has a 20-page limit including, but not limited to: table of contents, pages intentionally left blank, references, letters of support, appendices, technical portions of subcontract documents [e.g., statements of work and resumes] and all 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 other sections of the proposal submission as THESE WILL COUNT AGAINST THE 20-PAGE LIMIT. Any information that details work involved that should be in the technical volume but is inserted into other sections of the proposal will count against the page count. ONLY the electronically generated Cover Sheet and Cost Volume are excluded from the Technical Volume .pdf 20-page limit. Army Phase I proposals submitted with a Technical Volume .pdf document of over 20-pages will be deemed NON-COMPLIANT and will not be evaluated.

5. The Cost Volume has been completed and submitted for both **the Phase I and Phase I Option** and the costs are shown separately. The Army requires that small businesses complete the Cost Volume form on the DOD Submission site, versus submitting within the body of the uploaded proposal. The total cost should match the amount on the cover pages.

6. Requirement for Army Accounting for Contract Services, otherwise known as CMRA reporting is included in the Cost Volume (offerors are instructed to include an estimate for the cost of complying with CMRA).

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

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

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

10. If applicable, Foreign Nationals are to be identified in the proposal.

ARMY

ARMY SBIR 20.1 Topic Index

A20-001	ARMORS (Augmented Reality Maintainer-Operator Relay System): Real-time maintenance management software
~~A20-002~~	~~MR3: Maintenance Refuse Retrieval Robot~~ [Removed]
A20-003	True Harvard Architecture RISC-V DSP
A20-004	Using Artificial Intelligence to Optimize Logistics and Sustainment Trade-offs
~~A20-005~~	~~Carbonitriding Process Optimization of High Alloy Stainless Steel for Enhanced Wear and Fatigue Performance~~ [Removed]
A20-006	Articulated Landing Gear for Class IV UAS
A20-007	Compact Thermal Solutions through Advanced Manufacturing Techniques
A20-008	Additively Manufactured Functionally Graded Radomes for Hypersonic Vehicles
A20-009	Transient Combustion Effects on Observable Signatures of Maneuvering Hypersonic Configurations
A20-010	Optimization of Ceramic Matrix Composite (CMC) Interfaces
A20-011	Anomalous Dispersion Enhanced Inertial Sensors
A20-012	Metal Matrix Feedstock for Additive Manufacturing
A20-013	Low Thermal Touch Display
A20-014	Counter Swarming
A20-015	Laser Enhanced Aerodynamic Drag Reduction (LEADR)
A20-016	Integrated Radar and Electronic Surveillance (ES) system
A20-017	Harvesting Thermal Energy for Novel Power Sources in Long Range Precision Fired Artillery
A20-018	Novel Energy Harvesting Technology for Unattended Sensors
A20-019	Development of a Robust and Reliable Ignition Assistance System for Multi-fuel Capable Engines
A20-020	Integrated Hybrid Gear/Shaft Technology for Rotorcraft Drive Systems
A20-021	MId-wave infrared PIC-based coherent beam combining
A20-022	Scalable Process for Novel Nanomaterials with Infrared Filtering Properties
A20-023	Ultra-low Size Weight and Power-Cost (SWAP-c) Tactical Free Space Optical Communication System
A20-024	Laser Formed Fabrication of Conformal and Non-Conformal Millimeter and sub-Millimeter Wave Antennas
A20-025	Probabilistic Genotyping Software for Mixture Deconvolution of Next Generation Sequencing Data
A20-026	Graphene-Based Composite EMI Shielding for RF Device Protection
A20-027	Advanced Ceramic Matrix Composite Gas Turbine Engine Research Combustor
A20-028	On-Site Formate Production
A20-029	Non-Intrusive Pressure Measurement in Cannon Gun Tubes
A20-030	Independent Gun Location and Gun Tube Pointing Device
A20-031	Soft Catch System for Large Caliber Ammunition
A20-032	Laser Site Propagation Turbulence Profiling and Forecasting
A20-033	Application of Artificial Intelligence/ Machine Learning/Deep Learning to the Test and Evaluation of Command, Control, Communication and Intelligence (C3I) systems
A20-034	Voice Quality and Call Completion Rate for an Operational Radio Test
A20-035	High Energy, High Power 5V Electrochemical Energy Storage Solution
A20-036	Network Assisted Positioning, Navigation and Timing (PNT) in Low RF Signal Power Environments with Bandwidth Efficient Techniques
A20-037	Dynamic Frame Rate Throttling for High Resolution Low Light Cameras
A20-038	Cyber Terrain and Electromagnetic Operating Environment (EMOE) Scenario Generation Toolkit (CTAEMOESGT)
A20-039	Air Surveillance Radar Classification Improvement
A20-040	Mitigation of GMTI Radar False Alarms Due to Wind-Blown Foliage with Machine Learning

	Techniques
A20-041	Low Probability of Intercept Sense Thru Wall Radar
A20-042	Federated/Encrypted Biometrics System (FEBS)
A20-043	Innovative Approaches for Aided Target Recognition (AiTR) of Army Targets
A20-044	Novel Single Plane Optics for Lightweight, Compact Imaging Systems
A20-045	Additive Nanostructured Arrays (ANA) for Broadband Anti-Reflectivity (AR)
A20-046	Self-Healing Optical Elements
A20-047	Energy Storage with an Embedded Battery Management and Inverter Subsystem
A20-048	Next Generation Hybrid Power Technologies for 2 – 5 kW Power Systems Supporting Soldier Applications in the Multi-Domain Battlespace
A20-049	Small Arms Bullet Tracking Techniques and Algorithm Developments for Improved Soldier Lethality
A20-050	Dual-Band Lens SWAP Reduction and Increased Optical Throughput with Calcium Lanthanum Sulphide (CLS)
A20-051	Algorithm-Based People Detection and Threat Determination from Passive Infrared and Visible Cameras
A20-052	Moving Target Designation
A20-053	Cooperative and Coordinated Decentralized Warfare in Disconnected, Intermittent, Limited bandwidth (DIL) Environments
A20-054	High Fidelity IR Clutter Generator for Missile Warning Sensors
A20-055	Prioritized Tactical Data Exchanges
A20-056	Packaging Metal-Coated Fibers for Prolonged Storage and Efficient Dissemination
A20-057	Development of an Infrared Obscurant Produced In Situ from a Combat Vehicle
A20-058	Disseminating Obscurants at Mach I
A20-059	Mesoscale Model Capability Informed by Cemetitious Composite Microstructure
A20-060	Detection and Classification of Small Moving Objects Floating in/on Water Using Long Wave Infrared Imaging Polarimetry or Combination of Radio, Laser Detection and Ranging Radar Technologies
A20-061	AI Based Autonomous Agents that Possess Human-like Cognitive Skills in a Real-Time Strategy Game Environment
A20-062	Atmospheric Water Harvesting Tool
A20-063	Brain-Inspired Few-Shot Object Recognition
A20-064	Reduced Signature Powered Parafoils
A20-065	Haptics-enhanced Augmented Reality Training System for Care Under Fire
A20-066	Vehicle Mounted Expandable Command Posts (VMECoP)
A20-067	Advanced Materials for Power Electronics
A20-068	Additive Manufacturing (AM) for Aviation Shop Sets
A20-069	Phased Array SATCOM System for Group 2 UAS (Tactical BLOS)
A20-070	Cross Domain Processing Solution (CDPS) for Group 2 UAS
A20-071	Radio Network Sniffer and Baseband Signal Analysis Tool
A20-072	Machine Learning Waveform Agnostic Electronic Warfare Countermeasures for Army Tactical Radios
A20-073	Every Camera a Biometric Checkpoint
A20-074	Profile-to-Profile Face Recognition Matching Capability
A20-075	Touchless Fingerprint Identification Toolkit (TFIT)
A20-076	Correlating Threat with Identity
A20-077	Network Enclosure Architectural Concept Improvement
A20-078	Artificial Intelligence Application for Air and Missile Defense Combat Identification, Planning and Weapon Assignment
A20-079	Improved Ground Based Fire Control Radar Interferometry Techniques
A20-080	Continuous-Time Digital Signal Processing (DSP) Using Reconfigurable Devices
A20-081	Visor Projected Display NVG Camera
A20-082	Docking Pouch for Soldier Electronic Devices
A20-083	Low-Latency, High-Bandwidth Expeditionary Mobile Data Networks for Supporting Future Live Training Simulation Capabilities
A20-084	Cyber Training Big Data Analytics and Visualizations

A20-085	Quantum Sciences Components for Space Applications
A20-086	Small Satellite Components for Space Applications
A20-087	Compact, Hemispherical Coverage Early Warning Detection and Track Sensor for Multi-Mission Applications
A20-088	High Power Coherent Beam Combined Laser for Army Platforms
A20-089	Tactical Beaconless Atmospheric Turbulence Measurements
A20-090	High Energy Laser Beam Absorption Diagnostics and Thermal Blooming Prediction System
A20-091	Tactical Ultrashort Pulsed Laser for Army Platforms
A20-092	Intelligent Lithium-ion 6T MIL-PRF-32565 Compliant Battery Maintenance & Charging System
A20-093	Multifunctional Metamaterials for Novel Interaction with the Environment
A20-094	Autonomous Trailer Hitch Couple/Decouple
A20-095	Design and Development of Hardened Autonomy Sensors (Lidar and Radar)
A20-096	Sensor suite for Ground Vehicle Survivability
A20-097	Engineered Synthetic Replacement for Army Heavy Transport Trailer Wooden Decking and Flooring.
A20-098	Energy Attenuation Bench Seat System
A20-099	Secure FPGA Zeroization for Military Systems Abandonment
A20-100	Reconfigurable Computer Architecture for Flexible Input / Output (I/O)

ARMY SBIR 20.1 Topic Descriptions

A20-001 TITLE: ARMORS (Augmented Reality Maintainer-Operator Relay System): Real-time maintenance management software

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop a software application to allow Soldiers to easily identify, document, and manage vehicle maintenance issues that includes an augmented-reality based guidance system for operators and mechanics.

DESCRIPTION: The Army's current approach to preventative vehicle maintenance is outdated and analog. Currently a soldier must locate the technical manual for the vehicle and follow the listed instructions. Any deficiencies, known as faults, are then written by hand on a paper form. Faults that cannot be immediately rectified must also have a fault code – found in the technical manual – listed next to the deficiency. Upon completion of the preventative maintenance the paper form is then passed to a mechanic to verify the faults, and passed again to a clerk who enters the faults into a software system that tracks the maintenance status of the fleet as well as locates or orders the required parts.

There are numerous pain points in this process. Technical manuals are sometimes missing and often damaged. The analog maintenance process also only captures faults as recorded and does not allow leaders to see when preventative maintenance was not performed at all, when steps were skipped, or faults were misidentified. The current process also does not make the vehicle maintenance history available to the operators and mechanics working on the vehicle line, leading to further misidentification of problems. The passing of the form to numerous people can lead to its loss and delayed entry into maintenance and supply chain management system. Human error in transferring fault codes from the manual, to a form also introduces error. Leaders have no way of managing this process without inserting themselves into the paperwork routing process, creating bottlenecks and increasing the time delay between fault identification and part sourcing. Lastly, this entire process is inefficient because it must occur sequentially and requires one busy Soldier to physically find another busy Soldier simply to pass a piece of paper. Automating this process will increase maintenance readiness of the Army's fleet of vehicles by assisting soldiers in performing preventative maintenance through visual aids and by allowing leaders to track the fault identification and verification process in real-time.

Capabilities of this solution could include (but are not limited to):

-A computer vision enabled augmented reality application, implemented on a handheld or headset computing platforms, that allows operators and mechanics to receive visual aids for maintenance activities and provide recommended solutions
-Real-time geolocation of vehicles with faults within the motorpool, ability to prioritize verification based on vehicle type, geography, bumper number, fault-type or other criteria
-Picture-taking capability to allow for remote verification of faults
-Integration with training manual so that fault codes, and part identification (and alternate identification) numbers appear when fault is identified
-Ability to see past maintenance history of a vehicle when conducting services to confirm past faults have been corrected, and visualize part status for outstanding faults

PHASE I: Develop a solution that either assists with either/both maintenance supply chain operations or provides visualize aids during maintenance for a single vehicle type. Solutions are not required to be part of integrated whole. Proposals will be evaluated on a holistic basis based on the value they provide to the Army, allowing for solutions with a different constellation of features to be scored based on usefulness to maintainers and operators.

PHASE II: Develop an integrated solution, implemented on handheld or headset computing platforms, that integrates both augmented reality assistance with maintenance activities and supply chain activities into a single platform for a single vehicle type. As with phase I proposals will be evaluated on a holistic basis to assess the value they provide to the maintainers/operators of vehicles based on the included features.

PHASE III DUAL USE APPLICATIONS: Develop application for numerous vehicle types that interfaces with existing maintenance status and supply chain systems to facilitate improved preventative maintenance and equipment procurement. Potential commercial applications of the technology exist within the transportation sector (automotive, airline, rail) and electronics repair industries.

REFERENCES:
1. N. Neethu and A. Bk, “Role of Computer Vision in Automatic Inspection Systems,” International Journal of Computer Applications, August 2015, pp. 28-31.

2. E. Mendivil, R. Solis, and H. Rios, “Innovative Augmented Reality System for Automotive Assembling Processes and Maintenance,” 2013 15th International Conference on Transparent Optical Networks.

3. M. Anastassova, J. Burkhardt, C. Megard, P. Ehanno, “Results from a user-centred critical incidents study for guiding future implementation of augmented reality in automotive maintenance,” International Journal of Industrial Ergonomics, Volume 35, Issue, 1, January 2005, pp. 67 – 77.

4. M. Januszka and W. Panfil, “Augmented Reality Techniques for Vehicle Maintenance,” Proceedings of the Institute of Vehicles, Volume 2, 2015, pp. 37 – 48.

5. E. Bottani & G. Vignali, “Augmented reality technology in the manufacturing industry: A review of the last decade,” IISE Transactions, 2019, Volume 51:3, pp. 284-310.

KEYWORDS: Vehicle maintenance; Augmented reality; computer vision; supply chain; heads-up display

A20-003 TITLE: True Harvard Architecture RISC-V DSP

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: RISC-V is an open source instruction set architecture (ISA). The offeror shall develop a RISC-V Digital Signal Processor (DSP) architecture using a true Harvard cache and bus architecture (completely separate instruction and data bus architecture).

DESCRIPTION: We are interested in RISC-V DSP architecture to create an open source DSP standard with preplanned expansion opportunities similar to the RISC-V design philosophy [1-5]. We are also interested in the benefits provided by a true Harvard architecture over a unified von Neumann architecture. A true Harvard machine can perform simultaneous program instruction and data memory operations. The cybersecurity benefits for completely separating (isolating) program instructions from data has been ignored by the computer industry.

The offeror shall develop a RISC-V DSP architecture using a true Harvard cache and bus architecture [6] (completely separate instruction and data bus architecture). We are not interested in a modified Harvard architecture [7] nor a von Neumann architecture [8]. The offeror shall develop a RISC-V DSP architecture which provides for fixed point and floating point complex multiply and add and other DSP related instructions with planned extensions for 64 bit and higher.

The offeror is required to meet the performance objectives (1)-(4) by comparing the performance of an equivalent RISC-V floating point microprocessor to the proposed RISC-V DSP. The only architecture differences between the RISC-V core and RISC-V DSP are the instruction extensions and architecture extensions to support DSP operations.
(1) For a 256 by 256 complex double precision floating point matrix, and an 8 by 8 complex double precision floating point convolution kernel, demonstrate a 20 % higher performance.
(2) For a 16k (1024*16) input sequence, and a 500 (or 501) tap double precision floating point, FIR Hilbert transform, demonstrate a 20 % higher performance.
(3) For a 16k (1024*16) point double precision, floating point complex number FFT, demonstrate a 50% higher

performance.
(4) For a 64k (1024*64) point double precision, floating point complex number FFT, demonstrate 10% less energy used for the calculation.
Higher performance definition: 20 % higher performance means 20% less wall clock time to execute.

PHASE I: For the Phase I proposal, offeror shall describe the feasibility of developing a true Harvard RISC-V DSP architecture using a hardware/software co-design approach. The phase I proposal must address requirements (1)-(5). Proposals that do not meet the requirements will be deemed non-compliant and will not be reviewed.

(1) Propose a co-design approach for RISC-V DSP architecture and DSP software extensions.
(2) Propose DSP extensions for RISC-V architecture and a path forward to standardize the proposed extensions.
(3) A design concept to achieve the performance metrics in the description section.
(4) Describe potential Army, DoD, and commercial applications; and
(5) Provide a business model to market (a) the proposed open source RISC-V DSP and (2) if the offeror chooses to develop a closed source version a second marketing plan.

For the phase I effort, the offeror shall demonstrate the feasibility of developing a RISC-V DSP architecture using a true Harvard machine architecture.
(1) Develop models, simulations, prototypes, etc. to determine technical feasibility of developing a true Harvard architecture RISC-V DSP.
(2) Deliver a System Architecture Report describing RISC-V DSP architecture.
(3) Publish a proposed, open standard for RISC-V DSP ISA and Harvard cache and bus Architecture.
(4) Write a report describing the benefits [9] and costs of a true Harvard architecture over a von Neumann architecture covering (1) higher bandwidth, (2) better isolation between instructions and data, (3) more parallelism, et al. The intention of this report is to (1) illustrate to the microprocessor community the parallel performance advantages of a Harvard architecture and (2) to show to the cybersecurity community that the isolation provided by a Harvard architecture is significantly better than a von Neumann architecture.

PHASE II: Phase II: Offeror shall develop a RISC-V DSP based on offeror's proposal and phase I effort. The offeror shall demonstrate RISC-V DSP for an Army application (like Joint Multi-Role Technology Demonstrator [10]). The Offer shall propose potential applications for a system demonstration and implement an application with government concurrence.

Offeror shall create an open source RISC-V DSP version in a standard hardware description language (VHDL, Verilog, SystemC, etc.) and provide an open source license. The offeror shall publish an open source architecture document covering RISC-V DSP (VHDL, Verilog, SystemC, etc.) code and system development board. Offeror is free to develop another version which may be fully proprietary.
Offeror shall deliver 2 prototype systems to the government point of contact for test and evaluation with all software tools and licenses (if required), and hardware description language code(s) and software to build and use the system. Offeror shall provide 2 days of on-site training for the system.

PHASE III DUAL USE APPLICATIONS: Offeror will develop and market RISC-V DSP based on phase II development work and marketing plan from phase I. Offeror may target low power applications or high end DSP market. Offeror will integrate RISC-V DSP into an Army Aviation or Missile subsystem currently under development or via technology refresh.

REFERENCES:
1. D. Patterson and A. Waterman: The RISC-V Reader: An Open Architecture Atlas, Strawberry Cannon LLC, 2017. ISBN 978-0-9992491-1-6.

2. C. Hua Chang: "RISC-V DSP (P) Extension Proposal," RISC-V Barcelona Workshop, 9 May 2019.

3. D. Schiavone, et al.: "DSP ISA Extensions for an Open-Source RISC-V Implementation," ETH Zurich Integrated Systems Laboratory. (no date).

4. P. Schiavone, et al.: “A near-threshold RISC-V core with DSP extensions for scalable IoT Endpoint Devices,” pre-print. https://arxiv.org/pdf/1608.08376.pdf

5. AndesCore™ AX25: http://www.andestech.com/product-details01.php?cls=3&id=111#

6. https://en.wikipedia.org/wiki/Harvard_architecture

7. https://en.wikipedia.org/wiki/Modified_Harvard_architecture

8. https://en.wikipedia.org/wiki/Von_Neumann_architecture

9. P. Jungwirth, et al.: "Cyber defense through hardware security", Proc. SPIE 10652, Disruptive Technologies in Information Sciences, 106520P (9 May 2018); doi: 10.1117/12.2302805; https://doi.org/10.1117/12.2302805

10. http://www.defenseinnovationmarketplace.mil/resources/JMR_AMRDEC01.pdf

KEYWORDS: RISC-V, digital signal processing, Harvard machine, Hardware/Software Co-design

A20-004 TITLE: Using Artificial Intelligence to Optimize Logistics and Sustainment Trade-offs

TECHNOLOGY AREA(S): Information Systems

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

OBJECTIVE: Develop methods to use artificial intelligence (AI), machine learning, and real-time computational intelligence to optimize Army logistics and sustainment simulations and predictions for both legacy and future Army aviation systems. Identify aviation platform life cycle metrics, such as Materiel Availability (Am), Operational Availability (Ao), sparing, cost, maintenance man-hours, and other KSA's, to be optimized by AI. Provide to a logistics engineer knobs to turn to see effects on metrics such as system reliability, system availability, system downtime, administrative delay time, maintenance man-hours, manpower, and OPTEMPO.

DESCRIPTION: The CCDC AvMC Logistics Engineering Lab (LogLab) developed a sustainment simulation capability for Army aviation using a government-owned software tool called System of Systems Analysis Tool (SoSAT). Multiple PM's use this capability to conduct analysis and provide input for major acquisition documents. The LogLab is looking to upgrade the simulation capabilities of the software tool using artificial intelligence and machine learning to optimize logistics outcomes for CCDC AvMC customers like Future Vertical Lift (FVL). Artificial intelligence would determine strategies of sparing, costs, supply chain locations, maintenance staffing, maintenance levels, scheduled maintenance times, to best measure and optimize sustainment options and logistics support for Army aviation and weapon systems. SoSAT is a government-owned software package and will be provided. Notional and/or representative Army aviation reliability and supply data will be used. The size of the dataset will also be representative of actual datasets used and expected to be used by future Army aircraft -- a typical 30-year Army aviation model is approximately 25GB, and multiple models could be combined, yielding datasets in the range of 100-200GB. Any AI solution will need to run on US government network computers and will be export controlled.

PHASE I: Perform a design study to determine how to use artificial intelligence, machine learning, and real-time computational intelligence to optimize sustainment and logistics support. Deliver a final design of AI's capabilities, a simulation model of Army aviation assets, and a demonstration of an AI-infused logistics model capable of making intelligent trade-off decisions to meet specified PM threshold and objective sustainment metrics -- specifically, downtime and readiness levels as calculated by Army aviation, using inputs such as failure rates, ALDT, repair times, and maintenance man hours. A successful design will be able to optimize support, minimizing aviation system downtime and maximizing aviation system availability, using logistics inputs (component failure rates, repair part shipping times, repair times, maintenance man hours and maintainer staffing). Designed AI must be capable of handling, learning from, living in, and analyzing datasets upwards of 200GB in size. Designed AI must also show a 75% reduction in results data processing time over current methods, a 10% reduction in data input, import, and formatting time over current methods, and a 30% reduction in output dataset size. Test method to determine success for above metrics will be accomplished through analysis.

PHASE II: Deliver and implement a working prototype of an AI-infused logistics model (as designed in Phase I) capable of deep learning and making intelligent trade-off decisions to meet specified PM threshold and objective sustainment metrics. The model will also provide the capability to measure the impacts of technology insertions, obsolescence, reset, and other significant events in the entire Army aviation platform's life cycle, and to optimize such downtime and upgrade scheduling over that typical life cycle (30-50 years). Prototype AI must be capable of handling datasets upwards of 200GB in size. Prototype AI must be able to learn from baseline sustainment datasets, learn from excursion datasets on the fly, and apply learned behaviors. Prototype AI must show a 100% reduction in results data processing time over current methods, a 20% decrease in data input, import, and formatting time over current methods, and a 50% reduction in output dataset size. Test method to determine success for above metrics will be accomplished through demonstration. Mission profiles and operations in the model will be based on notional Army aviation and weapon concept of operations (CONOPS).

PHASE III DUAL USE APPLICATIONS: Deliver a polished and complete working AI-infused logistics sustainment model making intelligent trade-off decisions to meet specified PM threshold and objective sustainment metrics to all Army PM's and for all Army aviation platforms. The final product should model and optimize logistics and sustainment at multiple levels of fidelity from battalions to component parts, from individual missions to entire 50-year life cycles, use advanced web and cloud services to compute and be hardware-independent, may include an asynchronous mobile application to view and sort results, handle upwards of 1TB of data, and be hosted or otherwise available to all CAC-enabled personnel. Test method to determine success for above metrics will be accomplished through operations.

REFERENCES:
1. Rosienkiewicz, Maria. (2013). “Artificial Intelligence Methods in Spare Parts Demand Forecasting. Logistics and Transport.” 2013.

2. Real Carbonneau, Kevin Laframboise, Rustam Vahidov. “Application of Machine Learning Techniques for Supply Chain Demand Forecasting.” European Journal of Operational Research, Vol. 184, Issue 3, 1 Feb 2008, pp. 1140-1154.

3. C. Jennings, D. Wu and J. Terpenny, "Forecasting Obsolescence Risk and Product Life Cycle With Machine Learning," in IEEE Transactions on Components, Packaging and Manufacturing Technology, vol. 6, no. 9, pp. 1428-1439, Sept. 2016.

4. Bellochio, Andrew T. (2018). “A Framework to Enable Rotorcraft Maintenance Free Operating Periods.” 2018.

5. Pukish, M.S.; Reiner, P.; Xing Wu, “Recent advances in the application of real-time computational intelligence to industrial electronics,” IECON 2012 – 38th Annual Conference on IEEE Industrial Electronics Society, pp. 6305, 6314, 25-28 Oct. 2012

KEYWORDS: artificial intelligence, logistics, simulation, modeling and simulation, sustainment, availability, reliability, maintainability, supportability, software development, machine learning, neural networks, real-time computational intelligence, data science, software architecture, deep learning, support vector machines, Levenburg-Marquardt, particle swarm optimization

A20-006 TITLE: Articulated Landing Gear for Class IV UAS

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Develop an actively controlled, legged, articulated landing gear which significantly improves rugged landing capabilities of large UAS air vehicle. The articulated landing gear will also support landing under degraded visual environments (DVEs), shipboard landing, and extreme terrain operations.

DESCRIPTION: Landing safely on uneven ground in unprepared areas and landing safely on a pitching and rolling ship represent two of the greatest challenges faced by rotorcraft conducting military operations today. It is often impossible for UAS operators to know the slope dynamics of the micro-terrain below them when landing in these environments at night, or in DVE. Compounding this problem is on-site, non-aviation ground personnel that may be unaware of landing limitations; or remote operators with limited awareness of landing site topography. Conducting these types of landings is a difficult task even for UAS operators and can lead to air vehicle accidents during military operations. The use of an actively aircraft controlled articulated robotic landing system can mitigate a large portion of the aforementioned risks. These actively controlled legs allow the air vehicle to conform to uneven and sloped terrains and significantly reduce the cognitive loads placed on the autopilot system. Progress has been made towards the development of such systems, with theoretical and computational models being developed to simulate the rigid body dynamics and controls involved in the design of an articulated landing gear [1-3]. The concept of articulated robotic landing gear has also been successfully demonstrated and flight tested on a small scale (~200 lbs.) unmanned helicopter [4].

An additional benefit of actively controlled landing system is its ability to enhance hard landing survivability. The system can act as a shock absorber with a relatively large stroke, and through active and passive control, can spread impact loads over longer duration times hence reducing active and passive control, can spread impact loads over longer duration times hence reducing loads seen by the landing gear and the airframe. Studies conducted using rigid body simulation tools have shown that such a system can reduce peak loads by 70 to 90% for particular landing conditions when compared with conventional landing gear [1].

This program will investigate the capability of actively controlled robotic landing gear as a benefit of replacing traditional landing gears with such a system. The focus of the project is on evaluating the capabilities of such a system through design, fabrication, and testing. The end result should be a validated design and simulation package for the deployment of these system to various UAS platforms. Towards the goal of commercialization, the system should be sized for a four-legged Class IV UAS in the 3,000-5,000 lbs. gross weight range and subsequently analyzed using a comprehensive simulation tool set. The program should explore optimization of the design for landing in extreme conditions while maintaining the capabilities of the system as an articulated landing gear and minimizing weight. The program should also define criteria for material selection when sizing the system for various aircraft. The use of advanced materials such as carbon fiber reinforced polymer (CFRP) composites should also be explored.

PHASE I: The awardee will study a robotic landing system sized for a helicopter or vertically landing Class IV UAS in the 3,000-5,000 lbs. gross weight range and investigate its capabilities to land in extreme environments. Detailed trade studies should be performed including studies on drive system power draws, system weight and volume in various modes, and drag. The study should include stress analysis to prove crashworthiness while optimizing the design for weight minimization. Determine potential automation software, structural, and other failure modes, effects, and mitigations. Also should determine increase in suitable landing zones available for design concepts for various slopes (e.g. % earth with < 7 deg slopes vs. % earth with < 25 deg slope and variations in landing surface quality) and resultant operational impacts that may mitigate weight penalties. An experimental test plan for characterizing and validating the modeling tools used in the design process should also be proposed as part of this effort. The study should address weight savings/penalties over comparable conventional landing gear. Lastly, assess suitability for limited ground mobility.

PHASE II: The awardee will fabricate a working prototype and experimentally validate its capabilities. Awardee is expected to perform mechanical characterization experiments to calibrate all modeling requirements, predict the systems capabilities, and experimentally validate model predictions. Using the experimentally validated simulation tools, scaling factors and contributing issues will be clearly articulated in the final report with an assessment for scaling up to the 7,000 lbs. and 21,000 lbs. range.

PHASE III DUAL USE APPLICATIONS: Integrate prototype into flight test demonstrators as a modular solution which may be added to existing platforms to increase mission capabilities. The system may also be repackaged for commercial UAS operators. Successful demonstration at this scale may provide future opportunities at larger scales as well as for manned rotorcraft/VTOL systems. Commercial opportunities may exist for surveying in areas of rough terrain, autonomous package delivery, and paramilitary and police “perch and stare” surveillance

REFERENCES:

1. Kiefet, J., Ward, M., and Costello, M., (2016). “Rotorcraft Hard Landing Mitigation Using Robotic Landing Gear”. Journal of Dynamic Systems, Measurement, and Control. 138(3). 2. Manivannan, V., Langley, J.P., Costello, M., and Ruzzene, M. (2013). “Rotorcraft Slope Landings with Articulated Landing Gear”. In AIAA Atmospheric Flight Mechanics (AFM) Conference (p. 5160). 3. Kim, D., and Costello, M. (2017) "Virtual Model Control of Rotorcraft with Articulated Landing Gear for Shipboard Landing."

2. Manivannan, V., Langley, J.P., Costello, M., and Ruzzene, M. (2013). “Rotorcraft Slope Landings with Articulated Landing Gear”. In AIAA Atmospheric Flight Mechanics (AFM) Conference (p. 5160).

3. Kim, D., and Costello, M. (2017) "Virtual Model Control of Rotorcraft with Articulated Landing Gear for Shipboard Landing." In AIAA Guidance, Navigation, and Control Conference. 2016.

4. DARPA Robotic Landing Gear Could Enable Future Helicopters to Take Off and Land Almost Anywhere, http://www.darpa.mil/news-events/2015-09-10. Demonstration video at https://www.youtube.com/watch?v=Ip_WqX8nmKY&feature=youtu.be

5. Di Leo, C. V., Leon, B., Wachlin, J., Kurien, M., Rimoli, J. J., and Costello, M. (2018). “Cable-Driven Four-Bar Link Robotic Landing Gear Mechanism: Rapid Design and Survivability Testing”. In 2018 AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (p. 0491).

KEYWORDS: Robotic, Landing Gear, Crashworthiness, Impact Mitigation, Unmanned Aerial Systems

A20-007 TITLE: Compact Thermal Solutions through Advanced Manufacturing Techniques

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Additive Manufacturing is a quickly growing field of technology that has been adopted across the military and even deployed on the ISS by NASA. The technology allows for the creation of complex components that cannot be achieved using traditional subtractive methods such as machining. The CCDC Aviation and Missile Center is interested in using Additive Manufacturing to create thermal management solutions to handle device heat fluxes of more than 1,500 watts per square centimeter, supporting high performance missile and radar electronic transceivers at a system-on-a-chip level enabling significant miniaturization beyond current state-of-the-art. Oscillating heat pipes rapidly remove localized heat by incorporating phase change material in capillary channels that oscillate between material states enabling large heat flux. Copper heat sinks structurally landscaped around printed circuit board components provide a path for the heat to be transferred. By utilizing advanced manufacturing techniques such as additive metal printing, complex geometries can be achieved that cannot be created through traditional subtractive manufacturing (machining). This topic is focused on 3” to 5” diameter thermal management solutions to support hypersonic missile, densely packaged Radio Frequency (RF) and electronic integration. Barriers to this development include, but are not limited to, the capability to print (additively manufacture) metal heat pipes with integrated wicking, bi-metal print capability, modeling and measuring heat generation and measuring effectiveness of the resulting thermal system prototype.

DESCRIPTION: It is the intent of this topic for the offeror to demonstrate the capability to create landscaped thermal management copper structures employing oscillating heat pipe technology. Proposals must employ metal additive manufacturing to generate the prototypes.

PHASE I: In Phase 1, the offeror shall research, develop and fabricate prototypes of wicking oscillating heat pipes that can handle device heat fluxes of more than 1,500 watts per square centimeter. A phase change material must be designed in the heat pipe. The heat pipe should be approximately 5-7 inches in length (knowing that effective thermal conductivity varies with heat pipe length), with a diameter less than 1/4”. The thermal structure should sustain heat transfer in variable gravity orientations. The final prototype of Phase 1 shall be printed using copper or similar thermally conductive material. The design shall be fully modeled and heat removal effectiveness simulated. Prototypes are required during Phase I and must be supplied to CCDC Aviation and Missile Center.

PHASE II: In Phase II, the offeror shall use methods developed in Phase 1 to research, develop, fabricate, and evaluate integrated thermal heatsinks ranging from 3” to 5” in diameter and less than 1/2” thickness (including all landscaped structures) using oscillating heat pipes within board-landscaped, additive copper or similar thermally conductive structures enabling cooling of system-on-a-chip processor technology with high throughput to handle device heat fluxes of more than 1,500 watts per square centimeter. This technology is aimed at supporting thermal management for direct sampling that would eliminate much of an analog receive chain for significant miniaturization. The desired products of Phase II include: 1) a developmental board design, 2) thermal analysis and design of an integrated solution using additive structures, pockets of phase change material and oscillating heat pipes structured in a heatsink that would surround components of a Radio Frequency (RF) System-on-a-Chip (SoC) printed wiring board design, 3) prototypes of the landscaped thermal mitigation solution, 4) model/simulation results compared with measured effectiveness of the thermal system prototype. Heat generation levels should include that created through RF power amplification, general processing, and digital transceiver system components that would be highly integrated onto the heat sink-based thermal management solution resulting in a significant miniaturization of these type systems. Prototypes are required during Phase II and must be supplied to CCDC Aviation and Missile Center.

In addition, the offeror shall expand the research and development to rugged prototypes of printed thermal management structures that can withstand environmental concerns including humidity, dust, shock, and vibration such as that of a missile launch and relevant lifetime. All results are to be fully documented, and before and after prototypes of evaluations are to be supplied to CCDC Aviation and Missile Center.

PHASE III DUAL USE APPLICATIONS: For Phase 3 of this effort, the offeror shall expand upon the thermal management solutions of Phase II to develop a fully integrated RF System-on-a-Chip processing structure at high throughput. The purpose of this demonstration is to show the level of efficiency using actual RF transceiver system components at a frequency of interest in the millimeter wave band. The prototype will consist of RF power amplification, and components to conduct direct sampling at the RF frequency to eliminate much of the analog receive chain to achieve miniaturization. The prototype shall be highly integrated onto the thermal management heat sink-based solution. Prototypes are required during Phase III and must be supplied to CCDC Aviation and Missile Center.

Phase 3 dual use applications: Particular military applications include generic radar sensor system applications for use on missile technologies that can be applied to hypersonic missile fight environments. Commercial applications include all high throughput processing system applications. Transitions of opportunity include both immediate and local capability generation of additively manufactured designs of thermal management solutions for highly integrated processing and RF system-on-a-chip sensors. The most likely path to transition for the thermal management technology is a commercial development or for a CCDC missile program such as Long Range Maneuverable Fires to adapt the technology during their development and test cycle. These programs run through 2029.

REFERENCES:

1. Ian Gibson, David Rosen, Brent Stucker, (2014), Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2014.

2. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications (with Companion Media Pack) - Fourth Edition of Rapid Prototyping, 2014.

3. Hod Lipson, Melba Kurman, Fabricated: The New World of 3D Printing, Wiley, 2013.

4. Andreas Gebhardt, Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing, Gebhardt, Andreas, Hanser, 2012.

5. US Dept of Commerce, Properties of Metal Powders for Additive Manufacturing: A Review of the State of the Art of Metal Powder Property Testing, NIST, 2014.

6. Van Osch, Thijs HJ, et al. "Inkjet printing of narrow conductive tracks on untreated polymeric substrates." Advanced Materials 20.2 (2008): 343-345.

7. Amit Joe Lopes, Eric MacDonald, Ryan B. Wicker, (2012) "Integrating stereolithography and direct print technologies for 3D structural electronics fabrication", Rapid Prototyping Journal, Vol. 18 Iss: 2, pp.129 – 143.

KEYWORDS: Heat Pipes, Thermal Management, Advanced Manufacturing, Metal Printing

A20-008 TITLE: Additively Manufactured Functionally Graded Radomes for Hypersonic Vehicles

TECHNOLOGY AREA(S): Materials/Processes

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an advanced additive manufacturing technology for constructing functionally graded radomes for use in missiles and other hypersonic vehicles.

DESCRIPTION: Radome is a cover or enclosure that protects radar antennas from environmental influences, and made from an electromagnetically transparent material. The radome can have a huge influence on sensitivity, radiated antenna pattern and immunity to vibrations. Minimization of microwave reflection at the surface of the cover should be a key aspect in designing a radome, and therefore, materials with low dielectric constant (< 5) and low loss tangent (< 5~10%) are needed without compromising thermal and mechanical characteristics required for the target environment. For hypersonic vehicles at Mach 5~10 (1~2 miles/sec), the temperature of the aircraft can reach anywhere from 1500C to 2000C. Thus, the radome materials must also satisfy certain unique thermal and mechanical requirements relevant to the harsh operating environment. Among them, high melting temperature >3200F (or >1760C), high flexural strength >50-100 MPa and high Young’s modulus > 50-100 GPa are critical parameters. In addition, high thermal conductivity, low water absorption, low density, high particle, rain and thermal impact resistance, and high mechanical strength, hardness, and flexibility are also important characteristics depending on the application.

Different radome wall structures have been used, including half-wave wall, thin wall, A-sandwich, B-sandwich, C-sandwich, multilayer, and graded radome wall structures. Half-wave wall or thin wall radomes are individual layer radome materials suitable for narrow band applications. Layered and graded radome wall structures are used for broadband radome applications. Conventional sandwich or layered radome wall structures are typically fabricated by epoxy bonding which has a limited range of operation temperature and, therefore, they suffer from delamination at high operation temperatures due to mismatched thermal expansion coefficients. Functionally graded radome wall structures enable the combined properties for hypersonic radomes, and are under intensive research. Additive manufacturing processes are based on layer-by-layer manufacturing, which constitute an excellent fit for fabricating the functionally graded radomes for hypersonic vehicles. At the same time, the additive manufacturing has numerous advantages such as rapid prototyping with a fast turn-around time, low-cost entry, low waste generation and high energy efficiency. Additive manufacturing also allows fabless designing 3-D complex structures like composition and functionally graded radomes by using commercially available software and fabricating the structures at remote shared facilities for additive manufacturing, and hence lowering the costs.

Besides the selection of materials and fabrication processes, the electromagnetic design of functionally graded radomes is also highly critical for the optimum radome performance for hypersonic vehicles. Radome materials and structure must be carefully designed for minimum transmission loss in the desired frequency bandwidth and minimum boresight error, in addition to the other electromagnetic, thermal, mechanical, and environmental requirements. These interrelated challenges must be addressed with a combination of materials selection, functional graded radome wall structure, electromagnetic design, and innovative manufacturing technologies.

PHASE I: Identify candidate radome materials and facilities capable of high temperature electrical, thermal, and mechanical testing of the radome materials for temperatures ranging from 500C to 1500C. Develop high temperature material characterization capabilities at small sample sizes and perform high temperature (from 500C to 1500C) material characterizations: thermal testing (thermal expansion coefficient, thermal conductivity, melting temperature, and thermal capacity), electrical testing (dielectric constant and loss tangent for different frequency bands from 50 MHz ~ 50 GHz, and resistivity), and mechanical testing (flexural strength, Young’s modulus, and Poisson’s ratio). Develop an electromagnetic design of functionally graded radome materials (FGRMs) with melting temperature >1760C, a low dielectric constant (< 5), low loss tangent (< 5~10%), high flexural strength (> 50-100 MPa), and high Young’s modulus > 50-100 GPa for hypersonic vehicles operating at temperatures >1500C. Identify a feasible and scalable additive manufacturing process for the identified radome materials. Provide experimental data along with projected performance in the target environment.

PHASE II: Develop a scalable additive manufacturing process for the FRGMs and demonstrate the production of a scale-down version of a 3-D radome with functionally graded wall structures. Perform electrical, thermal, mechanical, and reliability testing of the radome across the temperature range from 500C to 1500C (required) / >1760C (desired). Optimize functionally graded radome material design and process and conduct detailed testing of the radome materials and fabricated 3-D structures for reaching the desired electrical, thermal, and mechanical requirements stated above for hypersonic vehicles. Demonstrate a scalable manufacturing technology during production of the radome materials. Validate process repeatability and demonstrate the ability of the FGRMs to withstand the simulated aerothermodynamics heating/loading in hypersonic flight environments and to ensure reliability and structural integrity of the proposed materials. Deliver a prototype of the scale-down version of the optimized 3-D radome to US Army for evaluations. Provide complete engineering and test documentation for the development of manufacturing prototypes.

PHASE III DUAL USE APPLICATIONS: Expand on Phase II results by optimizing the functionally graded radome as necessary for integration into a hypersonic defense system/advanced target vehicle. Develop and execute a plan to manufacture the functionally graded hypersonic radome developed in Phase II, and assist the transitioning this technology to the appropriate missile defense prime contractor(s) for the engineering integration and testing.

REFERENCES:
1. J.B. Kouproupis, "Flight capabilities of high-speed-missile radome materials," Johns Hopkins APL Technical Digest, 13, 386 (1992).

2. Shuqiang Ding, Yu-Ping Zeng, Dongliang Jiang, "Oxidation bonding of porous silicon nitride ceramics with high strength and low dielectric constant," Materials Letters, 61, 2277 (2007).

3. Zhangwei Chen, Ziyong Li, Junjie Li, Chengbo Liu, Changshi Lao, Yuelong Fu, Changyong Liu, Yang Li, Pei Wang, Yi He, "3D printing of ceramics: A review," Journal of the European Ceramic Society 39, 661–687 (2019).

4. Lim Chin Hwa, Srithar Rajoo, Alias Mohd Noor, Norhayati Ahmad, M.B. Uday, "Recent advances in 3D printing of porous ceramics: A review," Current Opinion in Solid State and Materials Science 21 323–347 (2017).

KEYWORDS: Radome, hypersonic vehicle, functional graded, hypersonic aerothermodynamics environment

A20-009 TITLE: Transient Combustion Effects on Observable Signatures of Maneuvering Hypersonic Configurations

TECHNOLOGY AREA(S): Battlespace

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Development of modeling tools that properly account for transient combustion effects on the observable signatures of maneuvering hypersonic configurations during extreme maneuvers.

DESCRIPTION: The Army has in interest in the observable signatures of hypersonic configurations during extreme maneuvers. Such configurations may employ liquid or solid propellant devices to provide thrust during said maneuvers. However, the associated accelerations are severe and can alter thruster chamber pressure and thrust level significantly. Such variations also occur near the end of liquid or solid propellant burns. As a result, the thrust characteristics, aerodynamic maneuverability, and observable signatures vary significantly from expected steady state conditions. Such changes in behavior must be taken into account when designing survival tactics for offensive assets or when designing and testing detection, track, and guidance algorithms for defending assets. Consequently, the Army seeks modeling tools that can predict the transient combustion effects on the observable signatures of liquid and solid rocket motor thrusters employed by hypersonic configurations during extreme maneuvers.

PHASE I: Develop a physics-based modeling technique that fully accounts for the three-dimensional flowfield and chemical kinetics combustion processes that occur within liquid and solid propellant motors during extreme maneuvers and produce observable effects, to include soot and smoke trails, on the resulting exhaust plume signatures. It is expected that the technique will also incorporate the ability to address in-flight ignition transients and thrust tail-off.

PHASE II: Integrate the model from the Phase I effort into the current DoD plume flowfield modeling tools. Demonstrate the capability for several transient configurations of interest to the Army. Assess the integrated modeling suite against available plume signature data (visible/IR). Deliver the modeling software in source code and executable format along with all files needed to compile and successfully execute to serve as a prototype for evaluation and cybersecurity assessment by the Government. Deliver technical and software user documentation, model demonstrations and assessment cases with results for Army use. Maximum practical use of existing plume flowfield modeling software is desired to reduce development and validation costs.

PHASE III DUAL USE APPLICATIONS: Demonstrate applicability of the newly developed capability for multiple configurations of interest to the Army. Commercialization: The capability to accurately account for transient combustion effects on the observable signatures of maneuvering hypersonic configurations will enable the DoD, including MDA, to significantly improve their respective abilities to predict what US configurations will look like to its adversaries and what threats to US assets will look like to sensors on-board defending assets.

REFERENCES:
1. Salita, M.; “Modern SRM Ignition Transient Modeling (Part 1): Introduction and Physical Models”, AIAA-2001-3443, July 2001.

2. "Nonlinear Combustion Instabilities and Stochastic Sources" V.S. Burnley, Ph’D Thesis, California Institute of Technology, Pasadena, CA, 1996.

3. "Some Influences Of Nonlinear Energy Transfer Between The Mean Flow And Fluctuations," F.E.C. Culick, G.C. Isella, California Institute of Technology, Proceedings of the JANNAF Combustion Meeting, CPIA-PUB-662-Vol-II, Oct 97.

4. "Nonlinear Unsteady Combustion Of A Solid Propellant." G.A. Flandro, University of Tennessee, Proceedings of the JANNAF Combustion Meeting, CPIA-PUB-662-Vol-II, Oct 97.

5. "Stability Testing of Full Scale Tactical Motors," F.S. Blomshield, J.E. Crump, H.B. Mathes, R.A. Stalnaker and M.W. Beckstead, NAWCWD, China Lake, AIAA Journal of Propulsion and Power, Nol. 13. No. 3, pp. 349-355, May-June 1997.

6. "Nonlinear Stability Testing of Full-Scale Tactical Motors," F.S. Blomshield, J.E. Crump, H.B. Mathes, C.A. Beiter and M.W. Beckstead, NAWCWD, China Lake, AIAA Journal of Propulsion and Power, Nol. 13. No. 3, pp. 356-366, May-June 1997.

7. "Pulsed Motor Firings," F.S. Blomshield, NAWCWD, China Lake, NAWCWD TP 8444, March 2000.

KEYWORDS: Transient, combustion, liquid rocket engines, solid rockets, observable signatures, hypersonic, maneuver

A20-010 TITLE: Optimization of Ceramic Matrix Composite (CMC) Interfaces

TECHNOLOGY AREA(S): Materials/Processes

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Demonstrate a computational tool for material and process development of ceramic matrix composite (CMC) that can assist in minimizing production time and optimize density, compression and tensile strength, toughness and thermal stability of the resulting CMC composites for missile structures. The computational tool will be informed by an enhanced understanding of the effect of time, temperature and processing conditions on the fiber/matrix interphase region which is in direct relation to the mechanical properties of the composite.

DESCRIPTION: Army missile systems strive to improve performance while maintaining affordability. Lightweight, high-temperature composite materials are required to continue system performance improvements. A key parameter contributing to the performance of CMC structures is the interaction between the fiber and matrix during production and operation. Gaining an enhanced understanding of the fiber/matrix interphase region will support development of computational tool for material and process development of CMC structures.

PHASE I: Develop a proof of concept for a computational tool, based on a comprehensive understanding of the CMC's fiber/matrix interphase variables of effect as they relate to time, temperature and processing conditions. Baseline the cost for a material and process system (for an applicable missile structure). Optimize the cost of materials and processes in pursuit of a 40% reduction in costs as compared to baseline. Performance will be measured by the material characteristics of the resultant mechanical properties generated by the tool to include tensile and compressive strength, as well as density and void content.

PHASE II: Demonstrate the ability to fabricate an applicable CMC missile structure at a processing cost of 40% less than baseline. The solution should be tailored to optimize the composite tensile and compressive strength, toughness and thermal stability for temperatures ranging from 500°C to 1500°C. The tailored properties should be demonstrated by testing and documented to include fiber/matrix interphase properties, compressive strength, tensile strength, void content, and density. Deliver comprehensive engineering and test documentation of the applicable structure.

PHASE III DUAL USE APPLICATIONS: Demonstrate a commercially-viable CMC solution in a representative missile structure with tailored mechanical and physical properties generated by the optimization tool. The tailored properties should be demonstrated by testing. The fiber/matrix properties should be evaluated and documented. Additionally, support transitioning the technology to suitable prime contractors for further engineering development, integration, and testing.

REFERENCES:
1. Naslain, Roger R. "Fiber-reinforced ceramic matrix composites: state of the art, challenge and perspective." Kompozyty (Composites) 5 (2005): 1.

2. Glass, David. "Ceramic matrix composite (CMC) thermal protection systems (TPS) and hot structures for hypersonic vehicles." 15th AIAA International Space Planes and Hypersonic Systems and Technologies Conference. 2008.

3. Yang, Jinshan, Shaoming Dong, and Chengying Xu. "Mechanical response and microstructure of 2D carbon fiber reinforced ceramic matrix composites with SiC and Ti3SiC2 fillers." Ceramics International 42.2 (2016): 3019-3027.

4. Bansal, Narottam. (2006). Handbook of Ceramic Composites. Kluwer Academic Publishers.

KEYWORDS: Ceramic, Fiber/matrix interaction, Interface region, Surface Science, Carbon

A20-011 TITLE: Anomalous Dispersion Enhanced Inertial Sensors

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a prototype optical inertial navigation sensor that exploits anomalous dispersion to enhance the overall signal to noise performance of the inertial sensor.

DESCRIPTION: Much work has been performed in recent years on exploring the potential of utilizing anomalous dispersion to enhance the sensitivity of optically-sensed inertial navigation sensors such as Ring Laser Gyroscopes (RLGs), Passive Cavity Gyroscopes, and optically sensed accelerometers. Theoretical calculations and laboratory experiments have confirmed that sensitivities can be enhanced through the use of anomalous dispersion. While theoretical calculations have shown that it should be possible to anomalous dispersion to result in a net increase in sensor performance, in laboratory experiments to date, the attenuation in the optical signal (introduced by the absorptive media that also introduces the anomalous dispersion) has been larger than the increase in the sensitivity enhancement, resulting in a net decrease in overall inertial sensor performance. This solicitation seeks innovative approaches to this challenge to develop an optical inertial sensor design and readout architecture wherein the employment of anomalous dispersion results in laboratory and prototype demonstrations of an inertial sensor that has a net increase in the overall signal to noise. Incorporation of anomalous dispersion enhancement to optical inertial sensors has the potential to significantly increase the performance of inertial navigation systems at relatively low cost, resulting in a decreased dependence on the Global Positioning System (GPS).

PHASE I: In Phase I the offeror shall research and develop a theoretical model of an optically sensed inertial sensor (gyroscope or accelerometer, active or passive) whose net signal to noise ratio should increase when anomalous dispersion enhancement is introduced into the optical system. The offeror shall develop a laboratory experiment that demonstrates consistency with the theoretical predictions of the developed model including a demonstration of an increase in the overall signal to noise ratio when anomalous dispersion enhancement is introduced into the optical system.

PHASE II: In Phase II the offeror shall research and develop a theoretical model of an integrated prototype of the optically sensed inertial sensor (gyroscope or accelerometer, active or passive) demonstrated in Phase I. The offeror shall fabricate the prototype sensor and demonstrate that the prototype sensor demonstrates consistency with the theoretical predictions of the developed model including a demonstration of an increase in the overall signal to noise ratio when anomalous dispersion enhancement is introduced into the optical system. Potential military and commercial applications will be identified and targeted for Phase III exploitation and commercialization.

PHASE III DUAL USE APPLICATIONS: The use of inertial navigation sensors is pervasive in commercial applications including automobiles, gaming consoles, and mobile phones. Successful demonstration of anomalous dispersion enhancement could lead to significant improvements in the performance of these sensors which could lead to a significantly expanded application space in both the commercial and military industries

REFERENCES:
1. M. S. Shahriar, G. S. Pati, R. Tripathi, V. Gopal, M. Messall, and K. Salit, “Ultrahigh enhancement in absolute and relative rotation sensing using fast and slow light,” Phys. Rev. A 75(5), 053807 (2007).

2. D. D. Smith, H. Chang, L. Arissian, and J. C. Diels, “Dispersion enhanced laser gyroscope,” Phys. Rev. A 78(5), 053824 (2008).

3. D. D. Smith, K. Myneni, J. A. Odutola, and J. C. Diels, “Enhanced sensitivity of a passive optical cavity by an intracavity dispersive medium,” Phys. Rev. A 80(1), 011809 (2009).

4. H. N. Yum, M. Salit, J. Yablon, K. Salit, Y. Wang, and M. S. Shahriar, “Superluminal ring laser for hypersensitive sensing,” Opt. Express 18(17), 17658–17665 (2010).

5. K. Myneni, D. D. Smith, J. A. Odutola, and C. A. Schambeau, “Tuning the scale factor and sensitivity of a passive cavity with optical pumping,” Phys. Rev. A 85(6), 063813 (2012).

6. C. A. Christensen, A. Zavriyev, M. Bashkansky, and A. C. Beal, “Compact, fiber-based, fast-light enhanced optical gyroscope,” Proc. SPIE 8722, 87220J (2013).

7. N. B. Phillips, I. Novikova, E. E. Mikhailov, D. Budker, and S. Rochester, “Controllable steep dispersion with gain in a four-level N-scheme with four-wave mixing,” J. Mod. Opt. 60(1), 64–72 (2013).

8. D. D. Smith, H. Chang, K. Myneni, and A. T. Rosenberger, “Fast-light enhancement of an optical cavity by polarization mode coupling,” Phys. Rev. A 89(5), 053804 (2014).

9. E. E. Mikhailov, J. Evans, D. Budker, S. M. Rochester, and I. Novikova, “Four-wave mixing in a ring cavity,” Opt. Eng. 53(10), 102709 (2014).

10. J. Scheuer and S. M. Shahriar, “Lasing dynamics of super and sub luminal lasers,” Opt. Express 23(25), 32350–32366 (2015).

11. D. D. Smith, H. A. Luckay, H. Chang, and K. Myneni, “Quantum-noise-limited sensitivity-enhancement of a passive optical cavity by a fast-light medium,” Phys. Rev. A 94(2), 023828 (2016).

12. J. Yablon, Z. Zhou, M. Zhou, Y. Wang, S. Tseng, and M. S. Shahriar, “Theoretical modeling and experimental demonstration of Raman probe induced spectral dip for realizing a superluminal laser,” Opt. Express 24(24), 27444–27456 (2016).

13. J. Hendrie, M. Lenzner, H. Afkhamiardakani, J. C. Diels, and L. Arissian, “Impact of resonant dispersion on the sensitivity of intracavity phase interferometry and laser gyros,” Opt. Express 24(26), 30402–30410 (2016).

14. J. Wiersig, “Enhancing the sensitivity of frequency and energy splitting detection by using exceptional points: application to microcavity sensors for single-particle detection,” Phys. Rev. Lett. 112(20), 203901 (2014).

15. J. Wiersig, “Sensors operating at exceptional points: general theory,” Phys. Rev. A 93(3), 033809 (2016).

16. S. Sunada, “Large Sagnac frequency splitting in a ring resonator operating at an exceptional point,” Phys. Rev. A 96(3), 033842 (2017).

17. J. Ren, H. Hodaei, G. Harari, A. U. Hassan, W. Chow, M. Soltani, D. Christodoulides, and M. Khajavikhan, “Ultrasensitive micro-scale parity-time-symmetric ring laser gyroscope,” Opt. Lett. 42(8), 1556–1559 (2017).

18. David D. Smith, Hongrok Chang, P. F. Bertone, Krishna Myneni, Louis M. Smith, and B. E. Grantham, “Closed-loop superluminal passive cavity,” Opt. Express 26(12), 14905–14914 (2018).

KEYWORDS: Inertial sensor, gyroscope, accelerometer, anomalous dispersion, dispersion enhancement, positioning, navigation, PNT, GPS-denied navigation.

A20-012 TITLE: Metal Matrix Feedstock for Additive Manufacturing

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Develop a metal matrix composite (MMC) feedstock that can be used in additive manufacturing to produce metal matrix composite parts. The desired feedstock would be analogous to the slit tape used in the polymer composites industry for tape placement. This MMC tape can then be used in ultrasonic additive manufacturing (UAM), or similar process, to create MMC components. The feedstock should have greater than 50% fiber volume and have no fibers present on the surface of the tape.

DESCRIPTION: The Army has a need for strong lightweight structures across multiple Cross Functional Teams (CFTs). Not only in primary structures such as gun tubes, muzzle brakes, and air frames but also in other components such as projectile bodies. Polymer composites are often called on for these applications but they lack high temperature capability and are often weak in the matrix dominated direction. Metal Matrix Composites (MMC) offer the possibility to obtain steel like strength and stiffness in the fiber direction with the density of aluminum. At the same time, the MMC retains aluminum level strength and stiffness in the matrix dominated direction.

The problem with MMC's has always been fabricating them. Generally this has been done by either consolidating powder or infiltrating molten aluminum into a ceramic fiber architecture. Both of these tend to be expensive processes and severely limit the size of the part that can be fabricated. What is needed is a feedstock / process that is analogous to the fiber / tape placement process used in polymer composites. In that process a fully consolidated tape of either thermoset or thermoplastic material is used to build a composite structure one layer at a time via sheet lamination. For thermosets the part is cured after this process. For thermoplastics the part is fully consolidated during the process.

There have been attempts to use Ultrasonic Additive Manufacturing to create MMC components out of sheets of MMC material. These efforts have met with mixed results. To date the MMC feedstock has fibers on its surface which are broken during the UAM process and damage the sonotrode. The work around for this was to use a thin sheet of pure aluminum between the MMC feedstock and the sonotrode but that severely lowered the possible fiber volume fractions.

This topic seeks to develop an MMC feedstock that can be used via UAM (or similar solid state joining process) to fabricate MMC parts of arbitrary size while maintaining a fiber volume fraction greater than 50%. The feedstock and manufacturing process should retain the Additive Manufacturing capabilities of UAM in that interior voids and features are capable of being produced.

PHASE I: Develop a process to fabricate metal matrix composite (MMC) feedstock with a fiber volume greater than 50%. The feedstock should be in tape form with a thickness on the order of 0.005" to 0.015" thick and a width on the order of 0.25" to 0.5". The preferred composite composition is an aluminum matrix with continuous aluminum oxide fibers (Nextel 610 or equivalent). The fibers should be uniformly dispersed throughout the tape but the surfaces should be pure matrix material. ASTM tests should conducted to demonstrate good adhesion between the fibers and matrix, and to determine the mechanical properties of the feedstock. These properties should be compared to theoretical predictions for the same fiber loading. Several layers of the MMC feedstock shall be consolidated via an additive manufacturing process and assessed for layer adhesion, fiber volume, fiber distribution and mechanical properties. The deliverable shall be 5 lbs of the MMC feedstock.

PHASE II: Refine the feedstock and produce it using a process representative of plant-scale production manufacturing. Increase the fiber volume with a threshold of 55% and a goal of 65%. No fibers should be visible on the tape surface. Sample MMC parts will be made and tested for mechanical properties. Minimum set of properties that shall be tested for are: longitudinal strength and modulus, transverse strength and modulus, Poisson's ratio, shear strength and modulus, compressive strength and modulus, and fiber volume. Minimum levels for longitudinal stiffness and strength are 30 Msi (207 GPa) and 210ksi (1450 MPa) respectively. All tests will be conducted according to relevant ASTM standards. Tests should be done to adhere the MMC feedstock to a steel substrate via additive manufacturing methods. The material deliverable will be a mutually agreed upon MMC part with a volume exceeding one cubic foot and with internal features. Additionally 25 lbs of feedstock shall provided.

PHASE III DUAL USE APPLICATIONS: In collaboration with the prime contractor and Benet Labs, apply a wrap to a complete gun tube for live fire testing in an operational environment. Explore automotive, down-well piping, and manufacturing technology applications for
the material. Adapt the low-cost manufacturing process to material applications with less stringent temperature requirements.

REFERENCES:
1. L. Burton, R. Carter, V. Champagne, R. Emerson, M.l Audino, and E. Troiano, Army Targets Age Old Problems with New Gun Barrel Materials, AMPTIAC Quarterly, v8n4, 2004. http://ammtiac.alionscience.com/pdf/AMPQ8_4ART08.pdf

2. A. Littlefield and E. Hyland, Prestressed Carbon Fiber Composite Overwrapped Gun Tube, November 2006. http://handle.dtic.mil/100.2/ADA481065

3. S. Montgomery and R. L. Ellis, Large Caliber Gun Tube Materials Systems Design, 10th U.S. Army Gun Dynamics Symposium Proceedings, Austin, TX, April 2002. http://handle.dtic.mil/100.2/ADP012479

4. Irick, V & Gordon, B. (2004). MetPreg™: Metallic prepregs for the composites industry. SAMPE Journal. 40. 8-15.

5. Hehr, Adam & Wenning, Justin & Norfolk, Mark & Sheridan, John & A. Newman, John & Domack, Marcia. (2018). Selective Reinforcement of Aerospace Structures Using Ultrasonic Additive Manufacturing. Journal of Materials Engineering and Performance. 28. 10.1007/s11665-018-3614-1

6. Obielodan, John & Stucker, Brent. (2014). A fabrication methodology for dual-material engineering structures using ultrasonic additive manufacturing. The International Journal of Advanced Manufacturing Technology. 70. 10.1007/s00170-013-5266-5.

KEYWORDS: Advanced composites, additive manufacturing, high temperature composites, metal matrix composites

A20-013 TITLE: Low Thermal Touch Display

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Design, develop and demonstrate a digital touch display that is capable of operating at very low temperatures and has minimal input power requirements.

DESCRIPTION: Small ruggedized electronic devices have been and are being developed for use by the warfighter and will play a critical role in most of the CFT capabilities to be fielded. Further these displays will be required to allow artificial, machine learning and the Internet of the Battlefield to enhance the warfighter and become a reality. These devices need to have the capability to operate in a wide range of environments and temperatures. Temperature range shall be described for this SBIR as 60°C to -40°C for operating and 71°C to -40°C for storage. Along with operating in server environments the warfighter is always looking to reduce the weight of his equipment and the length of time that the equipment can operate before batteries need to be replaced. Because of this the equipment being developed is looking for components that have minimal power needs and do not use heaters to achieve low temperature requirements. Minimal power consumption shall be described for this SBIR as a maximum of 10mW. This SBIR focuses on common displays that are used on these devices. A common display is described with (but not limited to) the following features: night readable, allow touch screen interface, 4K resolution, minimum 5 inch diagonal screen, capable of displaying common charter set at 18-Font, monochrome, readable from distance of 2 feet. The technology being developed should look to be scalable to match current displays on the market.

PHASE I: Investigate innovative approaches to develop displays to meet the topic requirements. Develop and document the overall component design and accompanying software interfaces.

PHASE II: Develop and demonstrate a prototype that can operate while meeting the above requirements.

PHASE III DUAL USE APPLICATIONS: Develop and demonstrate the technology developed in Phase II that is capable of being inserted into an existing ARDEC supplied system. Conduct testing to demonstrate feasibility of the component for operation within a simulation environment, and with actual fielded hardware.

REFERENCES:
1. https://pmmortars.army.mil/pmmortars/Products/lhmbc/

2. https://asc.army.mil/web/portfolio-item/soldier-nw/

3. https://asc.army.mil/web/portfolio-item/mortar-systems/

4. M777/M119 Howitzer

KEYWORDS: Display, Low, Temperature, Power, Electronic, Device, LCD, OLED, LED, Vacuum, Florescent, E-paper

A20-014 TITLE: Counter Swarming

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design and prototype counter swarm algorithms. This is a three part objective – (1) the prototype should be able to pick up on adversary swarm behavior based on sensor data; (2) The prototype should have algorithms that are able to translate the data associated from the adversary's swarm behavior into logical input into its own swarm; (3) create a swarm of autonomous agents that constantly ingest data from (2) and dynamically decide its action and try to counter the adversary swarm.

DESCRIPTION: Swarm technology—the ability of autonomous agents to autonomously make decisions based on shared information—has the potential to revolutionize the dynamics of conflict. And we're inching ever closer to seeing this potential unleashed. In fact, swarms will have significant applications to almost every area of national and homeland security.
There is a gap for detection, tracking and effective defeat of incoming threat swarm with the use of friendly swarm. The focus of the prototype should be the development of the algorithms that can decipher the swarm behavior of the adversary swarm, develop its own expert and effective Counter swarm algorithm and then implement its own swarm that targets the adversary swarm.

PHASE I: Investigate innovative methodologies and design concepts that can achieve the criteria for the system listed above. Develop design documents for the potential implementation of the system. Demonstrate a proof of principle of the design using simulated environment for a simple swarm pattern.

PHASE II: Further design, develop and demonstrate a prototype capability that meets the following three sub-objectives – (1) decipher simple and complex incoming swarm behavior based on simulated track data; (2) develop counter swarm algorithm in the same simulated environment that demonstrates the friendly swarm to effectively defeat the incoming threat swarm; (3) implementation of a small swarm that can ingest the counter swarm algorithms as input. Government will provide the threat swarm scenarios for (1).

PHASE III DUAL USE APPLICATIONS: Demonstration of full up swarm on swarm (n to n) field exercise – simple and complex. Government will provide the threat swarm scenarios.

REFERENCES:
1. https://www.cna.org/cna_files/pdf/DRM-2017-U-014796-Final.pdf

2. https://mwi.usma.edu/era-drone-swarm-coming-need-ready/

3. https://www.roboticsbusinessreview.com/unmanned/swarm-robotics-new-horizon-military/

KEYWORDS: CUAS, counter, unmanned, aerial, systems, swarm, network, drone, detection, tracking

A20-015 TITLE: Laser Enhanced Aerodynamic Drag Reduction (LEADR)

TECHNOLOGY AREA(S): Weapons

OBJECTIVE: To investigate, test and prototype the ability to reduce drag on a munition body by using laser energy/ discharge in order to decrease gun launched munition time of flight.

DESCRIPTION: This effort looks to research, prototype and demonstrate the ability to use off-body laser discharge to effectively reduce the drag and significantly decrease the time of flight of gun fired munitions. This effort has applicability to at least four (4) Army Modernization Priorities which have expressed the need for gun fired munitions to have more range. Initial efforts will be conducted within medium caliber munitions form factors (20mm to 50mm in diameter) but ultimately having applicability across munitions calibers and types. System effectiveness analysis will also be conducted in order to quantify operational utility and increases to system lethality.

PHASE I: Analysis and concept feasibility report analyzing the technology within medium caliber muniton (20mm to 50mm) form factors. Required power levels, possible drag reductions and preliminary mechanical and electrical integration feasibilities are to be determined. Analysis should be supported by relevant data.

PHASE II: Wind tunnel models for phase one chosen form factors, with functioning power generation and ability to create off-body laser discharge and resulting drag reduction within gun launched munition relevant Mach numbers.

PHASE III DUAL USE APPLICATIONS: TRL6/7 Technology demonstration of a gun launched munition, with onboard power generation, and LEADR system integrated into chosen munition form factors demonstrating the reduction of drag and increases in flight performance. Investigate the utilization of commercial components and manufacturing processes to ensure low cost munitions.

REFERENCES:
1. Adelgren, Russell, et al. “Energy Deposition in Supersonic Flows.” 39th Aerospace Sciences Meeting and Exhibit, 2001, doi:10.2514/6.2001-885.

2. Ali, A. W. “The Electron Avalanche Ionization of Air and a Simple Air Chemistry Model.” Naval Research Lab Washington DC, 1982, NRL-MR-4794.

3. Kianvashrad, Nadia, et al. “Effect of Off-Body Laser Discharge on Drag Reduction of Hemisphere Cylinder in Supersonic Flow.” National Aeronautics and Space Administration, 2017, ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170005880.pdf.

4. Kremeyer, Kevin, and Andrew V. Pakhomov. “Lines of Energy Deposition for Supersonic⁄Hypersonic Temperature⁄Drag-Reduction and Vehicle Control.” AIP Conference Proceedings, 2008, doi:10.1063/1.2931905.

5. Nicholson, David. “Laser Pulse Filamentation.” Laser Pulse Filamentation, 2011, large.stanford.edu/courses/2011/ph240/nicholson1/.

6. Osuka, T., et al. “Laser Energy Deposition Effectiveness on Shock-Wave Boundary-Layer Interactions over Cylinder-Flare Combinations.” Physics of Fluids, vol. 26, no. 9, 2014, p. 096103., doi:10.1063/1.4896288.

7. Sasoh, Akihiro, et al. “Drag Reduction of Blunt Body in a Supersonic Flow With Laser Energy Depositions.” 47th AIAA Aerospace Sciences Meeting Including The New Horizons Forum and Aerospace Exposition, 2009, doi:10.2514/6.2009-1533.

KEYWORDS: Drag reduction, munition guidance, munition, munition lethality, gun launched

A20-016 TITLE: Integrated Radar and Electronic Surveillance (ES) system

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Design and prototype a combined radar and ES system to detect, track, and identify UAS’s to be integrated with a weapon system. The system should be able to detect and track a UAS system using a radar and then transition to an ES mode at a much higher bandwidth to determine the UAS link characteristics to be able to correctly identify the threat. The system should be able to interleave both ES and Radar dwells as well as have a large enough bandwidth to accommodate all UAS bands.

DESCRIPTION: The combined Radar and ES system will help determine intent of UAS for site protection. Both ES and Radar systems can provide unique attributes of a UAS system to the operator. Radars are able to detect and track multiple UAS systems in order to provide a precise 3D location of the UAS system. ES systems can determine UAS transmitter characteristics in order to correctly identify the UAS system and also detect intercommunication between two UASs. Hence, the combined ES and Radar system will provide the operator with the necessary situational awareness of the UAS’s that are around the protected site. In addition, having one integrated system vs multiple systems integrated together will shrink the kill chain time line.

PHASE I: Investigate innovative methodologies and design concepts that can achieve the criteria for the system listed above. Develop design documents for the potential implementation of the system. Demonstrate a proof of principle of the design using simulated environment for a simple UAS system.

PHASE II: Further design, develop and demonstrate a prototype capability that meets the following objectives – (1) Develop hardware and software that is able to operate as both a radar and ES system. (2) Detect and track a UAS system and interleave both radar and ES dwells to gather information on the UAS system and intercommunication between two.

PHASE III DUAL USE APPLICATIONS: Demonstration of full up radar and ES system that can track and identify multiple UAS systems. Also develop signal processing algorithms to extract additional information from the UAS system.

REFERENCES:
1. http://mil-embedded.com/articles/common-and-systems-emerging-military-missions/

2. https://www.nutsvolts.com/magazine/article/radar_and_electronic_warfare_fund

3. https://www.eetimes.com/document.asp?doc_id=1278779

KEYWORDS: UAS, Radar, ES, bandwidth, systems, detection, tracking

A20-017 TITLE: Harvesting Thermal Energy for Novel Power Sources in Long Range Precision Fired Artillery

TECHNOLOGY AREA(S): Materials/Processes

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Investigate and develop innovative solutions for harvesting and converting heat generated during aerodynamic flight into electrical energy and power for precision guided munitions. The technology should be capable of surviving typical artillery gun launch loads and should conform to fit within an artillery projectile.

DESCRIPTION: The Army's Long Range Precision Fires mission expands the current portfolio of conventional artillery to advanced munition technologies with extended range capability (>70km). Extended range requires the projectile to fly to higher velocities and altitudes as well as longer flight times. At high Mach speeds the projectiles may be exposed to high temperatures and heat fluxes up to 3500°C and 1000 W/cm2 respectively. Additionally, due to extended flight times, the electronics required for precision guidance require more power in order to maintain operation throughout the flight. The presence of high heat fluxes results in waste heat into the projectile which could potentially damage critical electronics. This coupled with the need for new power sources to sustain operational capability of onboard electronics systems creates a new opportunity for the investigation of novel energy harvesting technologies that can remove the excess heat from the airframe via conversion to electrical energy. The new source of electrical energy can thus be used to power fuzes, guidance, navigation, and control technologies, actuation systems, and staging technologies.
The Army is currently looking for novel thermoelectric materials and thermoelectric generators (TEG) that extend the current state of the art in thermal limits (>1500F) and thermoelectric effectiveness (ZT>2). Materials of interest include, but are not limited to, low dimensional materials, nanocrystalline and nanocomposite materials, organics (conducting polymers), inorganics (tellurides, oxides, Half Heusler alloys, skutterudites, silicides, etc.,), and organic-inorganic composites.

PHASE I: During the Phase I contract, successful proposers shall conduct a proof of concept study that focuses on thermal energy harvesting materials and energy conversion technologies that can withstand and operate within varying thermal loads ranging from 5 W/cm2 to 700 W/cm2 and temperatures ranging from ambient to 2000°F (objective). Investigations should include analysis of material performance under transient thermal loading, potential power output (threshold of 100W and objective 250W), and generator efficiency (ZT>2). A final proposed concept design, including a detailed description and analysis of potential candidate electronics packages for the new power source, is expected at the completion of the Phase I effort.

PHASE II: Using the data derived from Phase I, in Phase II the proposer shall fabricate and integrate a prototype of the technology into a nominal projectile form-factor. Specifically the TEG shall conform to a volume = 1 in3. The proposer shall further their proof of concept design by demonstration that the technology can sustain power to a representative electrical component or system under thermal loading up to 15 minutes (objective) and by performing mechanical and thermal testing on the proposed materials and power generator architecture. Upon evaluation of the design through a critical design review, the prototype hardware's survivability shall be demonstrated via high G testing in an air launched munition and aerothermal ground testing. Information and data collected from these tests will be used to validate operational performance.

PHASE III DUAL USE APPLICATIONS: Phase III selections shall ruggedize the final design, identify large scale production alternatives, and fabricate 20 prototypes that can be integrated into a nominal projectile form-factor to be identified by the SBIR: Army 20 Topics and Concepts Government. Live fire tests will be conducted and the prototype integrated with projectile form-factor will have to withstand shock loads approaching 35,000g's. Phase III selections will develop of a cost model of expected large scale production to provide estimates of non-recurring and recurring unit production costs. Production concept for commercial application will be developed addressing commercial cost and quality targets. Phase III selections might have adequate support from an Army prime or industry transition partner identified during earlier phases of the program. The proposer shall work with this partner (TBD) to fully develop, integrate, and test the performance and survivability characteristics of the design for integration onto the vendor's target platform. COMMERCIALIZATION: High efficiency energy harvesting and conversion technologies are continually in demand by the aerospace and automotive industries. Commercial and dual applications of this technology include electrical power supplies for satellites, fuel cells and combustion engines such as for aircraft and ground transportation.

REFERENCES:
1. Ali Shakouri, Thermoelectric, thermionic, and thermophotovoltaic energy conversion, Baskin School of Engineering, University of California, 2005, https://apps.dtic.mil/dtic/tr/fulltext/u2/a458490.pdf

2. M. Brian Thomas, Thermoelectric Energy Harvesting in Small Caliber Projectiles, PowerMEMS, Washington DC, Dec 1-4 2009

3. https://news.mit.edu/2018/topological-materials-turning-heat-electricity-01174.
http://en.wikipedia.org/wiki/Mortar_(weapon).

4. Global Thermoelectric Materials Market https://www.prnewswire.com/news-releases/global-thermoelectric-materials-market-2018-anticipated-to-reach-78-8-million-by-2023--300762588.html

KEYWORDS: Energy Harvesting, Energy Conversions, Thermoelectric Efficiency, Seebeck effect

A20-018 TITLE: Novel Energy Harvesting Technology for Unattended Sensors

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: The goal of this effort is to determine the feasibility, develop concepts and demonstrate novel technology for harvesting 10-100 mW of power (average) in close proximity to energized conductors or overhead power lines.

DESCRIPTION: The Army's modernization priority for Network Command, Control, Communications and Intelligence (NC3I), requires a variety of sensing assets capable of intelligent, autonomous and reliable processing and communications. Unattended sensors have become more capable with technology advances, and can integrate with networks to provide raw, processed or fully analyzed sensor data. The sensors, processing and communications require power which can be provided by batteries, but even sub-Watt sensing assets require large, heavy batteries to operate for extended periods of time.

Advancements in technology have driven improved efficiency and cost in energy harvesting, especially with solar-based methods [1]. However, solar is not viable in many cases and is highly dependent on environmental conditions. Energy harvesting for many unattended technologies must be dependable in a variety of environments, especially indoors where sun exposure is unlikely. In addition, RF methods for Internet of Things (IoT) devices that harvest wifi/bluetooth signals are only applicable to a small sub-set of use cases. Such sensing assets are often located in close-proximity to strong 50 or 60 Hz electric and magnetic-fields produced by conductors providing power to loads or overhead power lines. These devices are ideally sustained by power extracted from these fields, enabling extended operation, although energy-harvesting from any ubiquitous source would enable in-situ placement of low-power sensing devices with no need for energy-related maintenance [2][3][4].

Viable energy-harvesting methods for low-frequency fields do not currently exist to provide enough power in a form factor suitable [5][6] for the majority of unattended sensing applications. The development of this technology would

greatly expand the number of viable permanent installation points for a future Army network of assets, and ensure minimal maintenance with respect to the powering of the devices. Low-power sensing devices typically consume 10-100 mW, depending on the application, which informs the amount of harvesting needed to operate the sensors indefinitely. Harvesting technology capable of sustaining sensing assets in the majority of emplacement scenarios near powered conductors (e.g., high/low-temp, day/night/indoors) will enable unattended operation and eliminate the logistical difficulties of wiring power or swapping batteries.
Phase I: Briefly describe expectations and desired results/end product. (Please spell out any acronyms. Save your work after each narrative.)
The Phase I effort will research concepts and determine the technical feasibility of harvesting energy in close proximity to overhead power lines or powered conductors. This effort should identify and define the physics of energy harvesting to be explored and the enabling technologies to capture and store that energy. The research will include studies on the effects of indoor and outdoor environments on the technology, to include extreme temperatures. The theoretical limits of energy extraction for form factors up to a maximum volume of 100 cm3 (no dimension to exceed 15 cm), factoring in all known/expected losses, will be determined. A successful technology design will be capable of producing at least 10 mW consistently in a 100 cm3 volume or less. This effort will produce a conceptual design for a harvesting technology that can be demonstrated in the Phase II effort.

PHASE I: The Phase I effort will research concepts and determine the technical feasibility of harvesting energy in close proximity to overhead power lines or powered conductors. This effort should identify and define the physics of energy harvesting to be explored and the enabling technologies to capture and store that energy. The research will include studies on the effects of indoor and outdoor environments on the technology, to include extreme temperatures. The theoretical limits of energy extraction for form factors up to a maximum volume of 100 cm3 (no dimension to exceed 15 cm), factoring in all known/expected losses, will be determined. A successful technology design will be capable of producing at least 10 mW consistently in a 100 cm3 volume or less. This effort will produce a conceptual design for a harvesting technology that can be demonstrated in the Phase II effort.

PHASE II: In the Phase II effort, the harvesting technology preliminary design from the Phase I effort will be finalized, fully designed and demonstrated. The system build will be capable of demonstrating sustained power output of at least 10 mW in a design volume of less than 100 cm3. The technology will be built and demonstrated in laboratory experiments and in a variety of environmental conditions. The demonstration will include testing at a variety of potential locations expected to provide reasonably large field strength, (e.g. near the exterior of 3-phase cables under load, under power distribution lines). Measurements of the power extracted during these test scenarios will be presented to demonstrate the technologies' viability as a sustaining source of energy for sensor operation. The system design, five functional units, and detailed performance evaluations will be delivered for government evaluation with the Phase II final report.

PHASE III DUAL USE APPLICATIONS: Following a successful system development and demonstration in Phase II, Phase III will extend the effort to refine the design. The finalized design will be suitable for the manufacturing of production quantities for both military applications and commercial markets. Commercialization would be of great interest to the electric power industry while also providing a new technology to assist in military efforts concerned with long-life unattended sensors

REFERENCES:
1. N. Lewis, "Research opportunities to advance solar energy utilization", Science 22 Jan 2016: Vol. 351, Issue 6271

2. F. Shaikh and et. al, "Energy harvesting in wireless sensor networks: A comprehensive review", Renewable and Sustainable Energy Reviews Volume 55, March 2016, Pages 1041-1054

3. Kim, H., Priya, S., & Uchino, K., "Modeling of Piezoelectric Energy Harvesting Using Cymbal Transducers", Japanese Journal of Applied Physics, 45(7), 5836–5840, 2006

4. Guo, L., & Lu, Q., "Potentials of piezoelectric and thermoelectric technologies for harvesting energy from pavements", Renewable and Sustainable Energy Reviews, 72,

5. S. Yuan, "Magnetic Field Energy Harvesting Under Overhead Power Lines",IEEE Transactions on Power Electronics Volume: 30 , Issue: 11 , Nov. 2015

6. Tashiro, K., Wakiwaka, H., & Uchiyama, "Y Optimization of AC-DC converter for magnetic energy harvesting device", Sixth International Conference on Sensing Technology (ICST), 2012

KEYWORDS: electric, magnetic, field, battery, power, energy, sensor, solar, harvesting

A20-019 TITLE: Development of a Robust and Reliable Ignition Assistance System for Multi-fuel Capable Engines

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: To develop and demonstrate a highly robust and reliable ignition system for an aviation diesel engine capable of igniting low ignition quality jet fuels.

DESCRIPTION: The Army has a critical need for an ignition source for Army Unmanned Aerial Vehicle (UAV) engines that can burn fuels with low ignition quality, characterized by the cetane number. Defense logistics agency's (DLA) fuel analysis has shown a wide variation in fuel properties including samples with poor ignition behavior. Combustion instability derived from low ignition quality fuels can lead to increased maintenance, loss of aircraft and capability, and increased risk to the Warfighter. A robust system for ignition energy assistance is critical to enable operation of propulsion systems using a wider range of fuel, allowing Army propulsion systems to be more tolerant to low ignition quality fuels. This will enable semi-independent operation for future Warfighters with reduced logistics burden. The highest priorities for this SBIR are that the ignition system be robust, similar in size and shape to existing glow plug technology, easy to install, and capable of operating in a military environment using a variety of fuels. Historically, glow plugs have been used to assist ignition of diesel engines during cold start conditions by increasing the combustion chamber temperature before fuel injection. However, existing glow plugs are not designed for long duration ignition-assistance because of operating temperature limitations and energizing response times. The proposed ignition assistance system should have similar geometrical, and weight restrictions as a glow plug. It should be capable of enduring engine environments which are prone to vibrations, pressure cycles and thermal stresses. A new ignition system design employing novel materials should be considered that will ensure consistent engine ignition, regardless of operating conditions and fuel types. The primary challenge of this application is the development of materials suited for each component of the device that are capable of withstanding the harsh environment. Current existing materials have potential to handle the high temperatures or high strengths, but have not yet been evaluated for the desired application. Through research and investigation, an optimal combination of materials can be identified that meets the restrictions imposed in this ignition system. The part of the device inside the engine block, should use materials capable of withstanding combustion temperatures, with surface temperatures reaching higher than 1600°C. The primary body material should be resistant to temperatures higher than 800°C, with the material for the transition section between the part inside the engine and the body having a tolerance of higher than 1000°C. A fracture toughness of higher than 15 MPa m1/2 is desired since the system is expected to perform at high reliability for no less than 1000-hr under such conditions. The system should have a response time of less than 1 sec and the igniter should be powered by aviation standard 28 Volt DC power. The system should also be capable of adjusting its output energy to match the requirements of the input fuel. The unit should operate in the extreme environments found at altitude, where pressures may be as low as 30 kPa (absolute) and temperatures as low as -40°C. With these requirements met, a new ignition system could be incorporated into compression ignition engines, allowing for their operability with different fuels, while mitigating the risks of engine damage and flame blow-out. With this risk abated, Army UAV engines will perform more reliably, enabling highly sought capabilities. The new ignition system will support the Future Vertical Lift Cross Functional Team (FVL CFT) via the "Multi-fuel capable hybrid electric" task within the Future UAS project in the Advanced Unmanned Aircraft System Line of Effort (AUAS LOE). Commercialization of this technology can allow for higher combustion reliability when used in terrestrial engines, and a high degree of insensitivity to variations in fuel properties for aerial applications.

PHASE I: Develop and design a new ignition assistance system concept that can meet the Army requirements of igniting low cetane number fuels (20-40) in extreme environmental conditions. The designed system shall be powered by 28 Volt DC. It shall operate at high surface combustion temperatures exceeding 1600°C, where output energy is controllable, and a fast response time of less than 1 sec from 400°C to 1600°C is attainable. It shall embody dimensional and operational characteristics that would enable its integration into compression ignition engines via a typical glow plug port for an existing system of comparable weight. Novel materials with suitable properties for the part inside the engine, main body, and transition section should be identified with measured fracture toughness (>15 MPa m1/2), and maximum allowable temperatures exceeding 1600°C, 800°C, and 1000°C, respectively. Additional operating requirements may be provided by the Army once contract award is made. The awardee shall provide a comparative analysis between the concept ignition assistance system and existing off-the-shelf technologies. CAD models should be supplied to the Army to determine interface compatibility with existing Army engines. The manufacturability of the proposed technology shall be assessed, identifying crucial fabrication process elements and projected production costs. The expected result is a thorough feasibility study, design, and proof of concept of an ignition assistant system. The success of Phase I will be judged based on the metrics of energy deposition level, response time, and fatigue analysis.

PHASE II: Develop and demonstrate the technology and manufacturing methods of the assisted ignition system. Assess and quantify the capabilities of the ignition system in realistic diesel engine operating conditions with a variety of Army supplied aviation fuels. Implement new materials that meet the Army requirements for fracture toughness and maximum allowable temperatures as part of the ignition assistant system. Parameters for assessment include the Army requirements of less than 1 sec response time, ignitability of low cetane number fuels (20-40), operating on a 28 Volt DC power supply, weight restrictions of less than 0.5 lbs and ability to perform with high reliability for no less than 1000-hr within conditions of a compression ignition engine. In addition, system complexity and ease of installation will be assessed. Manufacturing assessment will evaluate the method, repeatability, materials and tolerance-holding capability. Deliverables include a formal report, test and analysis results and (10) prototype sensors and hardware.

PHASE III DUAL USE APPLICATIONS: This technology, as envisioned, can be commercialized for terrestrial and aerial vehicles by increasing fuel insensitivity and therefore overall fuel efficiency, as well as providing a high degree of combustion reliability. A more direct impact will be on small manned and unmanned aircraft systems, which is a rapidly growing industry. A reliable ignition assistance system would allow for further development of multi-fuel capable aviation engine systems. This in-turn could facilitate the development of higher efficiency, reliable small UAV engines fueled with heavy fuels such as F-24, Jet A, diesel, and alternative, bio-derived heavy fuels. Success of the project would lead to more advanced and reliable propulsion systems for future commercial and DoD UAV systems.

REFERENCES:
1. Mueller, Charles J., and Mark P. Musculus. “Glow Plug Assisted Ignition and Combustion of Methanol in an Optical DI Diesel Engine.” SAE Technical Paper Series, 2001, doi:10.4271/2001-01-2004.

2. Aesoy, Vilmar, and Harald Valland. “The Influence of Natural Gas Composition on Ignition in a Direct Injection Gas Engine Using Hot Surface Assisted Compression Ignition.” SAE Technical Paper Series, 1996, doi:10.4271/961934.

3. Willi, M. L., and B. G. Richards. “Design and Development of a Direct Injected, Glow Plug Ignition-Assisted, Natural Gas Engine.” Journal of Engineering for Gas Turbines and Power, vol. 117, no. 4, 1995, p. 799., doi:10.1115/1.2815467.

4. Karthikeyan, B., and K. Srithar. “Performance Characteristics of a Glowplug Assisted Low Heat Rejection Diesel Engine Using Ethanol.” Applied Energy, vol. 88, no. 1, 2011, pp. 323–329., doi:10.1016/j.apenergy.2010.07.011

KEYWORDS: Ignition assistance system, igniter, multi-fuel capable engine, unmanned aerial system, compression ignition, altitude, aviation, performance, reliability, unmanned ground system

A20-020 TITLE: Integrated Hybrid Gear/Shaft Technology for Rotorcraft Drive Systems

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: The goal of this program is the development and application of innovative methods to design, build, and test a prototype composite integrated bevel gear/shaft design that is sized for a helicopter intermediate gearbox. This effort is expected to enhance the state-of-the-art and cover all aspects of hybrid gear development, including composite material selection, tooling, joining, and molding techniques, leading to the delivery of working prototypes.

DESCRIPTION: Propulsion systems on military (and commercial) helicopters are a key contributor to the overall weight of the aircraft. In some instances it accounts for almost 30% of the aircraft's empty weight. This percentage is expected to be even higher in the Army's future vertical lift (FVL) aircraft that employ more advanced variable speed transmissions due to the need for improved operational flexibility. Unfortunately, transmissions with variable speed capabilities are heavier than the fixed ratio transmissions currently in use due to the weight from the additional components. To counter the added weight and help meet Capability Set #1 and #3 requirements in FVL, the Army is currently pursuing innovations in hybrid gear technology where the steel hub is replaced by a strong, lightweight composite material. Recent experiments have successfully demonstrated the technology on a representative hybrid bull gear that was able to transmit 5000 Hp in a simulated transmission environment while weighing 20% less than the full steel counterpart. This approach is expected to reduce operating costs while increasing performance in terms of greater speed range and payload.
In an effort to reduce drive system weight even further, research is focusing on the concept of an integrated design by fabricating the gear hub and its adjoining steel shaft as one piece from a strong, lightweight composite material and then joining it with a steel gear. This approach builds on previous hybrid gear achievements and is the next logical step in reducing weight in rotorcraft drive systems. It also poses new challenges for the designer to identify the proper molding techniques and tooling to fabricate the composite material into an integrated, one-piece design.
Both the Army and Navy are very interested in utilizing hybrid technology to reduce the overall weight of a rotorcraft's main transmissions. However, demonstrating the viability of the technology in an actual main transmission would be expensive due to the high costs of running such a specialized test facility. For this research topic, the Army and Navy have selected a helicopter intermediate gearbox (IGB) as the technology demonstrator because of its relatively simple single gear pair reduction stage design that features two meshing bevel gears with integrated shafts supported by bearings. The bevel gear configuration adds complexity that should advance the state-of-the-art of hybrid gear technology. Whereas the hybrid bull gear was a double helical design with predominately torsional loads, the forces associated with bevel gears in the IGB are complex and include tangential, radial, and axial loads. This load environment requires advanced fabrication and joining techniques, especially at the composite material-bevel gear interface. The integrated assembly must meet the precise gear dimensional and performance specifications for aerospace applications and the tight dimensional tolerances on the shaft inner and outer diameter for balance requirements and the accommodation of tapered rolling element bearings.
The goal of this program is the research, development, and application of innovative technology and methods to design, fabricate, and experimentally evaluate a prototype composite integrated hybrid bevel gear/shaft technology that is applied to a helicopter IGB. This effort is expected to enhance the state-of-the-art and cover all aspects of hybrid gear development, including composite material selection, tooling, composite-metal joining, and molding techniques, leading to the fabrication and delivery of working experimental prototypes. The success of this effort will elevate the TRL to 6 and accelerate the implementation of integrated hybrid gear/shaft systems into rotorcraft drive systems.

PHASE I: Phase I should identify potential lightweight composite materials, tooling requirements, and molding processes that will enable the design and fabrication of an integrated hybrid bevel gear/shaft assembly that can withstand the speeds and loads present during endurance qualification tests for Army helicopter IGB's. The qualification tests for IGB's simulate normal cruise and more aggressive flight maneuver conditions. To simulate normal cruise the IGB transmits 524 shp with the input pinion operating at 4114 rpm and the output gear operating at 3318 rpm. Total time at this condition is 60 hrs. To simulate more aggressive flight maneuvers the gears are required to transmit 630 shp with the pinion operating at 4114 rpm and the output gear 3318 rpm. Total time at this condition is 30 hrs. Dimensional drawings for the pinion and gear assemblies will be provided by the government for design purposes. Each all-steel gear assembly (pinion and gear) currently weighs approximately 5.5 lbs. Major focus points of the effort should include maximizing strength while minimizing weight, identifying adequate joining techniques to connect the composite material to the steel bevel gear, and developing molding processes that can meet the strict dimensional tolerance requirements. The geometry of the hybrid gear/shaft assemblies should closely mimic the current all steel designs sufficiently to be drop-in replacements. Based on previous results it's expected a weight savings of at least 20% over the current design should be achievable. The final report shall identify the composite material, tooling, and molding processes for fabrication of the hybrid gear/shaft assemblies along with structural analysis to demonstrate the viability of the composite design to successfully complete the qualification tests.

PHASE II: Demonstrate the ability to fabricate and deliver at least two integrated hybrid gear/shaft prototypes based on the lessons learned in Phase I. The steel gear portion of the hybrid prototypes will be made available from all-steel input pinion and output gear assemblies from previously flown IGB's. The prototypes should be able to transmit 524 shp with the pinion operating at 4114 rpm and the output gear at 3318 rpm for at least 60 hrs. The prototypes should also be able to withstand the aggressive flight maneuver load of transmitting 630 shp for 30 hrs with the input pinion operating at 4114 rpm and the output gear at 3318 rpm. Their geometry should closely mimic the current all steel designs sufficiently to be drop-in replacements. The prototypes will be delivered to the Army and undergo flight qualification testing in the Helicopter Drive System (HeDS) Facility at Naval Air Station, Patuxent River, Maryland. The flight qualification tests will be conducted by the Army and any test data will be shared. It's expected successful completion of Phase II should boost the technology to TRL 6.

PHASE III DUAL USE APPLICATIONS: Commercialization of the technology enabling integrated hybrid gear/shaft designs should find a large market in both the military and commercial sectors. Major helicopter manufactures will use the technology to reduce weight, decrease operating costs, improve operational flexibility, and extend mission range. Successful integration will also propel the technology into other areas requiring power transfer and distribution

REFERENCES:
1. Handschuh, R.F., LaBerge, K.E., DeLuca, S., Pelagalli, R., "Vibration and Operational Characteristics of a Composite-Steel (Hybrid) Gear," NASA TM 2014-216646; ARL-TR-6973, 2014.

2. LaBerge, K.E., Handschuh, R.F., Roberts, G.D., Thorp, S., "Performance Investigation of a Full-Scale Hybrid Composite Bull Gear," American Helicopter Society 72nd Annual Forum Proceedings, West Palm Beach, FL, May 2015.

3. LaBerge, K.E., Johnston, J.P., Handschuh, R.F., and Roberts, G.D., "Evaluation of a Variable Thickness Hybrid Composite Bull Gear," Presented at the 74th Annual Forum of the American Helicopter Society, Phoenix, AZ, May 2018.

KEYWORDS: Gear, Hybrid Gear, Composite, Transmission, Drive System, Future Vertical Lift, Rotorcraft

A20-021 TITLE: MId-wave infrared PIC-based coherent beam combining

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: To create a monolithic, chip-scale mid-wave infrared photonic circuit that emits an order of magnitude more single mode average power than single emitters. Lasers should be directly coupled to the beam combining components either on the same chip or by effectively creating one "super-chip" containing the lasers and the beam combiner

DESCRIPTION: The coherent beam combining of semiconductor lasers has been pursued thru a number of methods. Major efforts have been pursued at near infrared diode laser wavelengths near 1 micron, with some success. Examples include the evanescent super-mode concept recently attempted for mid-wave infrared quantum cascade lasers which built upon prior work with shorter wavelength lasers. Although this approach may still be viable to a certain level, it is complex. More straight forward approaches are seen that leverage advances in low loss integrated photonics whereby lasers can be combined coherently from individual lasers spaced at any given degree as dictated most likely by thermal management consideration. Thus, the beam combining can leverage designs and processes developed over the past decade for the very best high power single mode mid infrared lasers to create a combined single mode output of ten times or more continuous wave power (from continuous wave input lasers). Research is progressing on these methods in the near infrared, but should now be investigated for U. S. Army needs at longer wavelengths. Much improved SWaP (Size, Weight, and Power) systems can be envisioned for a number of relevant applications.

Other approaches to direct diode near-IR beam combined lasers rely upon the spatial multiplexing of broad-area diode lasers through beam shaping optics. These approaches cannot provide the desired high brightness (or high coherence) since at best they can achieve the beam quality of a single high-power broad-area diode laser, which has a M2 value of ~10 or higher. In addition, these systems are usually realized by use of free space and/or fiber optical components, not suitable for chip-scale integration. However, it is well known that photonic integrated circuits (PICs) can significantly reduce the SWaP of many optical and laser systems and are under large scale research and development for use in telecommunications and data centers. Thus, the aim is to hereby use PICs to replace the bulk optics approaches in the current beam combining systems by encompassing recent advances in coupling from lasers to integrated waveguides and by use of low-loss silicon nitride or other very low loss integrated photonics materials that could significantly reduce the system SWaP and improve the beam quality. The potential research topic includes creating a PIC-based beam combining architecture, improving the coupling between semiconductor lasers and PICs, and increasing the power handling capability of PICs. Thermal management of closely spaced mid-infrared lasers including some kind of cooling may be a concern for studying the ultimate limits of such chip-scale approaches but would probably not be too challenging for a significant order of magnitude improvement over a single laser emitter.

Another consideration for one of the key applications would be achieving high modulation speed. Therefore, once the beam combining has been established one would also like to pursue the high speed modulation of such an array. Other considerations such as distributed feedback cavities for improved linewidth and modulation performance and coherence lengths may also be pursued.

PHASE I: Conduct research, theoretical analysis, and numerical studies on PIC based beam combining systems for high power single mode mid-wave infrared semiconductor lasers (3-5 micron wavelengths), develop measures of expected performance, and document results in a final report. The phase I effort should investigate specific PIC based laser beam combining system architectures and include modeling and simulation results supporting performance claims. The proposed beam combining system should use coherent beam combining and leverage state-of-the-art semiconductor lasers (average power and wall-plug efficiency of at least 1 W and 15% or more) at the chosen wavelengths. Simulations should show capability to scale the coherent combining of at least 10 lasers on chip of about 1 cm2 with close to 90% combining efficiency.

PHASE II: 1) Demonstrate PIC based beam combining of multiple (10 or more) 3-5 micron single mode semiconductor lasers with high beam quality (near diffraction limited) and experimental combining efficiency >85%; 2) Demonstrate high coupling efficiency (>90%) between the lasers and the beam combining PIC; 3) Explore the power scaling limits and power handling capability of the integrated beam combining systems. The data, reports, and tested hardware will be delivered to the government upon the completion of the phase II effort. 4) Begin studies of high-speed modulation of such beam combined arrays. Modulation speeds of at least 1 Gb/s are requested as the phase II goal at the 10 W power level.

PHASE III DUAL USE APPLICATIONS: Further scaling of power level and modulation speed can be pursued in the phase III. Applications of such mid-wave infrared lasers can be pursued for various military and civilian applications. Free-space laser communications systems can be developed and tested, and narrow linewidth distributed feedback or external cavity systems may be pursued for coherent lidar or other uses. Directed energy countermeasures type of applications would also be of interest. Industrial applications for material processing and fabrication may be desirable depending upon the power scaling potential. Scaling to much high power levels by using 100s of lasers (possibly with multiple PIC stacks) can be investigated experimentally.

REFERENCES:
1. S. Li and D. Botez, "Analysis of 2-D Surface-Emitting ROW-DFB Semiconductor Lasers for High-Power Single-Mode Operation", IEEE Journal of Quantum Electronics, Vol. 43, No. 8, August 2007.

2. Y. Zhu and L. Zhu, Integrated single frequency, high power laser sources based on monolithic and hybrid coherent beam combining, IEEE Journal of Selected Topics in Quantum Electronics 23, 8300908, 2018

3. M. Wilkens et al., 970-nm ridge waveguide diode laser bars for high power DWBC systems, SPIE Photonics West, Paper 10514-13, 2018

4. P. Crump et al., Limitations to brightness in high power laser diodes, IEEE Photonics Conference (IPC), pp. 553-554, 2015

5. J. D. Kirch, C.-C. Chang, C. Boyle, L. J. Mawst, D. Lindberg, T. Earles, D. Botez. 5.5 W near-diffraction limited power from resonant leaky-wave coupled phase-locked arrays of quantum cascade lasers, Applied Physics Letters, (02 2015): 61113.

KEYWORDS: coherent beam combining, mid-infrared lasers, photonic integrated circuits, free-space laser communications

A20-022 TITLE: Scalable Process for Novel Nanomaterials with Infrared Filtering Properties

TECHNOLOGY AREA(S): Materials/Processes

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a scalable process for the manufacture of nanoparticles that enable a narrow band of transmission within a broadband of infrared attenuation.

DESCRIPTION: Nanoparticles with tunable electromagnetic properties have the potential to impact a wide range of technologically relevant applications for both the Army and society as a whole. These particles play a vital role in technologies such as drug delivery, solar energy conversion, sensors, smart windows, and optical filters, to name a few. A subset of this research is the design and synthesis of nanoparticles, or collections of nanoparticles, that attenuate a broad region of the electromagnetic spectrum, while allowing for a narrow band of transmission. In recent years, research has demonstrated nanoparticles or collections of nanoparticles that exhibit a narrow band of transmission within a broadband of attenuation. These approaches have included: 1) nanoparticles with multiple resonances, e.g. multilayered particles that exhibit plasmon-plasmon coupling or plasmon-exciton coupling; 2) collections of nanoparticles that exhibit multiple resonances, e.g. mixtures of disparate nanoparticles that exhibit disparate resonances based on size and refractive index; and 3) nanoparticles that exhibit the Christiansen Effect at a given frequency, i.e. particles that have a refractive index that is close to the refractive index of the medium. While these nanomaterials have demonstrated promising optical properties, large-scale production and aerosolization challenges have not been resolved. Enabling the transmission of this narrow band of "light" is particularly attractive for those technologies in which "unwanted" or "harmful" bands of radiation are filtered out, thus enabling the "desired" radiation to reach a given substrate or receiver. For example, a glass-based smart window contains nanoparticles embedded in the glass designed to attenuate a vast region of the infrared region (thereby reducing heat in a given building), while simultaneously allowing for the transmission of a discrete band of IR radiation (e.g. a CO laser operating at a wavelength of 4 µm).

There is an essential need to research and develop a scalable process for manufacturing nanoparticles and associated powders that enable the transmission of a narrow band of infrared radiation while simultaneously attenuating broadband IR radiation as a whole. This will require a unique large-scale production process that can precisely control both particle size and shape. Additionally, the developed process should enable the removal of certain particle sizes and shapes from a given batch, enabling the generation of a potential transparency band. Hence, tunability of nanoparticle size and shape, and the ability to selectively remove various sizes and/or shapes from the manufacturing process are highly desirable. In this project, nanoparticles, or a collection of nanoparticles, are sought to enable the transmission of a narrow band of infrared radiation within any of the following infrared bands: near-IR (0.9-1.5 µm), shortwave IR (1.5-3.0 µm), mid-wave IR (3-5 µm), or long-wave IR (8-12 µm). In addition to the transmission requirement, broadband attenuation in all other regions of the infrared regions (NIR, SWIR, MWIR, and LWIR) is desired. Latitude will be given to the proposer in choosing the wavelength of transmission. This wavelength will largely be dependent on the physics and chemistry of the chosen nanoparticle(s). Preference will be given to those proposals that address manufacturability, and demonstrate the desired transmission can be exhibited as both a colloidal suspension and as an aerosol with minimal or no agglomeration. Demonstration of specific applications (e.g. smart windows) is not sought in this topic.

PHASE I: Demonstrate nanoparticles(s) with a transmission peak at a specific wavelength in the IR region and a transmission band with a bandwidth of 50 nm or less (full width at half maximum). A minimum pass to block ratio of 5:1 (in terms of transmission) is desired. Develop a process to fabricate 500 milligrams of the given nanoparticles, and using materials from this process, demonstrate the transmittance/extinction spectra as a colloidal suspension. Extinction of the particles(s) in the “block” region should be a minimum of 5 m2/g (as a colloidal suspension). Here, we define extinction as the sum of the absorption and scattering cross-sections, per unit mass of material, i.e. m2/g. This extinction term is typically determined via Beer’s Law, when the particle concentration (g/m3), the path length (m), and the transmittance are known. At the conclusion of phase I, provide 1 gram of fabricated powder to CCDC Chemical Biological Center.

PHASE II: Demonstrate a scalable process to achieve a minimum of 100 gram batches (up to 1 kilogram batches) of nanomaterial. Demonstrate the desired transmittance/attenuation spectra as an aerosolized powder, using samples taken directly from the batch process. Extinction of the particles(s) in the “block” region should be a minimum of 5 m2/g (as an aerosol). CCDC Chemical Biological Center will assist in the testing of the aerosolized materials. Provide CCDC Chemical Biological Center with 1 kilogram of material and manufacturing plans to achieve greater than 1 kilogram batches.

PHASE III DUAL USE APPLICATIONS: The proposed technology has a broad range of civilian and military applications. It is envisioned that these materials can be integrated into current and future military platforms which include laser protection systems, smart windows on vehicles, signature management, and camouflage systems. This technology could impact additional DoD interest areas in biomedical applications, sensors, and decontamination. In the civilian sector, advanced smart windows, catalysts, sensors, filtration systems, biomedical devices, and drug delivery systems are envisioned.

REFERENCES:
1. Bardhan, R., Mukherfee, S., Mirin, N.A., Levit, S.D., Nordlander, P., Halas, N.J., “Nanosphere-in-a-Nanoshell: A Simple Nanomatryushka”, J. Phys. Chem. C 114, 16, 7378-7383.

2. DeLacy, B.G., Miller, O.D., Hsu, C.W., Zander, Z., Lacey, S., Yagloski, R., Fountain, A.W., Valdes, E., Anquillare, E., Soljacic, M. Johnson, S.G., Joannopoulos, J.D., “Coherent Plasmon-Exciton Couling in Silver Platelet-J-aggregate Nanocomposite”, Nano Lett. 15, 4, 2588-2593.

3. Tanzid, M., Sobhani, Al, DeSantis, C.J., Cui, Y., Hogan, N.J., Samaniego, A., Veeraraghavan, A., Halas, N.J., “Imaging through plasmonic nanoparticles”, Proc. Natl. Acad. Sci. U.S.A. 2016, 113(20), 5558-5563.

4. Prost, R., “The Influence of the Christiansen Effect on I.R. Spectra of Powders”, Clays and Clay Minerals, 1973, Vol. 21, pp. 363-368.

KEYWORDS: Nanoparticles, Christiansen Effect, Multi-resonant nanoparticles, Fano Resonance

A20-023 TITLE: Ultra-low Size Weight and Power-Cost (SWAP-c) Tactical Free Space Optical

Communication System

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop an ultra-low space, weight, and power-cost (SWaP-c) Free Space Optical (FSO) communications capability for individual solider tactical operations in contested radio frequency (RF) environments.

DESCRIPTION: It has become imperative that the Army develop alternative capabilities to communicate with reduced electro-magnetic footprint, while assuring low probability to detect and low probability of incept (LPD/LPI) capability and supporting necessary bandwidth for modern battlefield operations. The Free-Space Optical (FSO) communication concept provides an alternative pathway for inherent LPD/LPI communications, while providing significant bandwidth and low electro-magnetic (radio frequency)emissions. One of the inhibiting factors preventing widespread use of traditional FSO communication systems based on macro-scale optics can be linked to their size, weight, complexity and overall cost per link. An ultra-low SWAP-c, FSO communication system could provide accessibility of this technology geared toward the Army need for ensured communication while on the move and at the lowest echelon.

Challenges associated with accomplishing this goal are many-fold and will require modern-day automated photonics technology manufacturing to achieve the long-term goal of a low cost while overcoming specific issues associated with pointing-and-tracking (PAT), transmitter beam divergence, receiving aperture size limitations, and low signal detection at GHz-level speeds. Given these challenges is it envisioned that one of the few solutions would be derived from modern integrated photonics technology

ARL is seeking a small business to demonstrate an ultra-compact FSO communication system. This demonstration should be capable of high bandwidth (Gb-level), low bit error rate (BER)(10-6), automatic PAT in an extremely compact form factor (< 100 cm3, 100s of grams, < 10 Watts of power consumption). There have been several rudimentary demonstrations of one necessary aspect for this program (e.g. wide-field of view beam steering) in a chip-scale form factor [1-2]. These systems might have the potential to address the SWAP-c requirements due to inherent size and long-term high volume fabrication pathway. Although these systems are interesting, none have demonstrated FSO communication functionality and there remains many impediments to embodiment of a full communication system that needs innovative and applied research and development to overcome. These ultra-compact FSO systems must overcome technical hurdles which the macro-scale system have done in past, including: aperture limits, low-signal detection at high data rate, full implementation of PAT with required field of view (FOV) and slew rates and finally low power consumption.

PHASE I: Complete a conceptual system design for a ultra-low space, weight, and power-cost (SWAP-c), (< 100 cm3, 100s of grams, < 10 Watts of power consumption), Free-Space Optical (FSO) communication system with delineation of critical elements and associated risk poised to meet the Phase II and III goals. Detail the key design considerations and trade-offs associated with the approach including scalability for cost. Develop prototype plans for Phase II. Demonstrate proof-of-concept of core link technology including rudimentary beam steering and modulation functions.

PHASE II: Demonstrate an initial prototype Free-Space Optical (FSO) communication system with data bandwidth of 1 Gbps, automatic pointing-and-tracking (PAT) function with 30 degree field of view (FOV) and maximum FOV slew time of 500 microseconds, bit error rate (BER) of 10-6 over 1-hour interval at 90% network capacity at an outdoor-range exceeding 200 meters in a modem form factor of 100 cm3 or less, weighing less than 400 grams and consuming 10 Watts or less power. Technology should be at the level of TRL 4/5 at the end of this phase with a dedicated plan toward fabrication scaling for reduced unit cost.

PHASE III DUAL USE APPLICATIONS: Advance prototype Free-Space Optical (FSO) communication system to TRL 7/8 with data bandwidth of 2 Gbps, automatic pointing-and-tracking (PAT) function with 45 degree field of view (FOV) and maximum FOV slew time of 500 microseconds, BER of 10-6 over 1-hour interval at 90% network capacity at an outdoor-range 1000 meters in a modem form factor of 50 cm3 or less, weighing less than 200 grams and consuming 5 Watts or less.

It is envisioned that this technology will enable near range dispersal of secure FSOC network for US tactical ground forces, which could also provide a dual-use commercial application pathway for local area networks in highly congested urban environments. Similarly a system of this type and capabilities would greatly reduce the cost of setting up urban Local Area Networks in developing areas. Applications of FSO communication system have direct pathway to transition through existing Army development investments currently underway for the alternative communication space. Finally, it is expected that the core of this technology will mature aspects of beam steering and integrated receivers, which could have direct dual-use in low SWAP-c laser ranging (LADAR) application for military and civilian use on autonomous platforms

REFERENCES:

1. Chung et al.: Monolithically Integrated Large-scale Optical Phased Array in SOI CMOS, IEEE Journal of Solid-State Circuits, Vol. 53, No. 1, January 2018

2. J. Sun, E. Timurdogan, A. Yaacobi, E. S. Hosseini, and M. R. Watts, "Large-scale nanophotonic phased array," Nature, vol. 493, no. 7431,pp. 195–199, Jan. 2013.

KEYWORDS: Photonics, Free-Space Optical Communications - FSOC, Optical, Communications, Local Area Network - LAN, Network, Laser, Light, Free-Space

A20-024 TITLE: Laser Formed Fabrication of Conformal and Non-Conformal Millimeter and sub-Millimeter Wave Antennas

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: The objective is to leverage recent advances in laser forming of metals to develop a cost effective manufacturing capability for conformal and non-conformal millimeter and sub-millimeter wave antennas that have complex shape, smooth surfaces, micron scale features, and bulk metal conductivity.

DESCRIPTION: Of interest to the Army is the potential for a given technology to merge capabilities and operate in contested environments which is a goal of the Network C3I Army Modernization Priority with which this topic aligns. Ultra-wideband (UWB) antennas that operate with several decades of bandwidth and cover millimeter and sub-millimeter wave (mmW and s-mmW) frequencies enable backend hardware flexibility without replacing the antenna. What's more, UWB antennas with complex shape that have polarization diversity can merge capabilities that require different polarizations and operate at different frequency bands. Fabricating antennas at mmW frequencies is challenging given the small features, especially when the antenna has a complex shape, such as a double curved surface. MMW antennas require micron-scale precision and high electrical conductivity. Additive manufacturing (AM) techniques are the current cost effective means for fabricating antennas of the prior description at sub-mmW frequencies, but the capability of AM to fabricate mmW antennas is limited.

While AM offers a fine level of control such that complex 3D geometries can be manufactured, the technology does have some particular limitations such as less than bulk metal conductivity inks and pastes that require plating and rough surfaces which can be detrimental to the antenna performance [1] – [4]. Multi-scale prints, where a large antenna has small features, can also pose a challenge for AM techniques, and the time to print multi-scale antennas can be extensive. Some of these challenges may not be so significant for some antennas, but is significant for antennas such as the ultra-wideband (UWB) and polarization diverse multi-arm conical sinuous antenna [5], the impulse radiating UWB TEM horn [6], or the high-power and high-gain slot array in waveguide [7] designed for millimeter and sub-millimeter wave (mmW and s-mmW) frequencies. As such, a technology gap exists.

A potential solution to the technology gap is a fabrication capability based on laser forming metal sheets. Laser forming is a method by which sheets of metal can be made to bend or buckle by the application of localized heat through a laser [8 – 9]. Judiciously choosing the locations and paths that the laser will heat can be used to create 3D shapes such as cuboids, coils, and doubly curved surfaces (e.g. the conical sinuous antenna and the TEM horn) [10]. Combining laser folding with laser cutting and welding allows for the manufacturing of closed geometries with features cut into them (e.g. the slot array in waveguide). Remaining research questions to be answered include thermal optimization of the process, improving sidewall roughness of cut surfaces, incorporation of welding, and process repeatability. In addition, developing the process such that the antenna technology developer can move a design from a computational electromagnetic modeling tool, such as HFSS, FEKO, or CST, to the laser device would better facilitate rapid prototyping of conformal antennas with small features.

Using laser induced heat to deform metallic sheets like copper, steel, and brass to make 3D shapes has been demonstrated [10 – 13]. Application of the technique to a slot array in waveguide at w-band was also attempted but the lack of a combined laser welding function prevented the antenna from being completely closed [13]. It has also demonstrated that aluminum foam can be bent using laser heating [14].

The laser formed fabrication of antennas would prove beneficial to the commercial sector. The new fabrication capability could prove cost effective and would expand the domain of antenna types that can be fabricated at mmW frequencies. The capability would also allow for the fabrication of smoother, more precise, and subsequently better performing conformal antennas.

PHASE I: Phase I shall explore the technical merit and feasibility of a laser forming based fabrication concept for mmW and s-mmW antennas to be executed in Phase II. The concept should prioritize commercially available laser systems. A study will address the research questions regarding optimal laser parameters for forming steel, aluminum, brass, and copper sheets with thickness ranging from 10 um to 1 mm to predict laser settings (i.e. power, exposure time, etc...) that are needed to optically cut, form, and weld the metal sheet into a 3D geometry and quantify the angle of resolution for bending and buckling. The laser cutting must achieve positional accuracy of no more than 10 microns, RMS surface roughness and line edge roughness less than 1 micron for both internal and external features, and minimum line width and spacing of 10 um. Laser forming angle resolution must be no more than one degree. The welding process must be within roughness spec, structurally robust, and maintain high electrical conductivity (>50% bulk conductivity). Documented process demonstration and study results are the primary deliverable.

PHASE II: Phase II will build on the Phase I concept by refining the process to fabricate and deliver two RF antenna prototypes that demonstrate the precision and repeatability of the Phase I process. The antenna designs are an upper W-band longitudinal shunt slot array and a 4-arm C- to upper Ka-band conical sinuous antenna. Antennas should be characterized through laboratory measurements of the reflection coefficient, radiation pattern, and efficiency. The measured results of the antennas and devices should be compared to simulation results acquired by using computational electromagnetic software such as CST, FEKO, or HFSS. The measured reflection coefficient should be better than -10 dB and the gain should be within 3 dB of the simulated results. The end of Phase II should demonstrate antennas using a complete laser forming manufacturing capability and deliver said antennas for evaluation.

PHASE III DUAL USE APPLICATIONS: Phase III will focus on the commercialization of fabrication technology for mmW and s-mmW antennas. The final process should demonstrate consistency and repeatability in manufacturing antennas for both military and commercial applications. Commercialization of the technology would be of use to the antenna development community as a whole by providing a cost effective means to producing high performance conformal antennas at mmW and s-mmW frequencies.

REFERENCES:
1. G. Zhang, et al., "Investigation on 3-D-Printing Technologies for Millimeter-Wave Terahertz Applications," Proceedings of the IEEE, Vol. 105, No. 4. April 2017.

2. C. R. Garcia, et al., "Effects of extreme surface roughness on 3D printed horn antenna," Electronics Letters, Vol. 49, No. 12. 6th June 2013.

3. B. Zhang, et al., "Metallic 3-D Printed Antennas for Millimeter- and Submillimeter Wave Applications," IEEE Transactions on Terahertz Science and Technology, Vol. 6, No. 4, July 2016.

4. B Zhang, et al., "Metallic 3-D Printed Rectangular Waveguides for Millimeter-Wave Applications," IEEE Transactions on Components, Packaging and Manufacturing Technology, Vol. 6, No. 5, May 2016.

5. M. Buck and D. Filipovic, “Two-Arm Sinuous Antennas”, IEEE Transactions on Antennas and Propagation, vol. 56, no. 5, May 2008.

6. V. Koshelev, “Ultrawidband Radiators of High-Power Pulses”, 28th IEEE International Conference on Plasma Science and 13th IEEE International Pulsed Power Conference, June 2001.

7. R. Gilbert, Waveguide Slot Antenna Arrays. In the Antenna Engineering Handbook 4th edition (J. Volakis ed.).

8. W. Li and Y. L. Yao, “Numerical and Experimental Study of Strain Rate Effects in Laser Forming,” Journal of Manufacturing Science and Engineering, Vol. 122, August 2000.

9. M. Geiger and F. Meyer-Pittroff, “Laser Beam Bending of Metallic Foils”, Second International Symposium on Laser Precision Microfabrication, Proceedings of SPIE Vol. 4426. 2002

10. N. Lazarus and G. Smith, “Laser Forming for Complex 3D Folding”, Adv. Mater. Technol. 2017.

11. N. Lazarus, S. Bedair, and G. Smith, “Origami Inductors: Rapid Folding of 3-D Coils on a Laser Cutter”, IEEE Electron Device Letters, vol. 39, no. 7, July 2018.

12. N. Lazarus and G. Smith, “Laser Folding in a Roll-to-Roll Manufacturing Process”, Lasers Manuf. Mater. Process. 2018.

13. G. Smith, N. Lazarus, and S. McCormick, “Laser Folded Antenna”, IEEE MTT-S IMWS-AMP 2018.

14. A Guglielmotti, et al., “Laser Bending of Aluminum Foam Sandwich Panels”, Advanced Engineering Materials 2009, 11, No. 11.

KEYWORDS: laser forming, sub-millimeter wave, millimeter wave, conformal, antennas, manufacturing processes

A20-025 TITLE: Probabilistic Genotyping Software for Mixture Deconvolution of Next Generation Sequencing Data

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Develop an expert probabilistic genotyping software system to reliably interpret next-generation sequencing (NGS) data using a fully continuous approach.

DESCRIPTION: Forensic DNA laboratories are preparing for the implementation of NGS technologies to supplement and eventually replace current capillary electrophoresis (CE)-based human identification. The advances in sequencing technology provided by NGS approaches allow interrogation of the human genome in new ways, enabling both short tandem repeats (STRs) and single nucleotide polymorphisms (SNPs) to be analyzed for forensic purposes within a single workflow. Utilizing NGS technology to analyze STRs allows the sequence of the repeat region to be viewed, enabling identification of isoalleles, alleles with the same length that contain unique sequences, which can further differentiate individuals who would otherwise have the same allele designation at a particular locus when analyzed using a CE-based analysis. These capabilities make NGS a powerful tool for forensic human identification and may ultimately enable resolution of even more complex mixtures than is currently possible [1] [2], but the transition to this technology also presents challenges. Data gathered from NGS analysis is more complex than CE-based data, and to take full advantage of the advanced capabilities in resolution of mixtures new software solutions are required.

Multiple software platforms exist to analyze raw NGS data and create a visual representation where mixtures and low-level samples can be interpreted manually by a DNA examiner. These software platforms, however, do not address how to reliably and objectively interpret complex DNA mixtures commonly seen in forensic DNA analysis, particularly for limited or degraded samples collected in operational environments. To enhance the amount of actionable information collected from DNA evidence and fully utilize the sequence information NGS offers, an expert probabilistic genotyping software system designed to analyze sequence information must be developed. The software must be compatible with data generated by currently available NGS STR and SNP chemistries. Furthermore, the software should enable data-in to answer-out analysis with minimal user interaction. The software must be capable of utilizing statistical theory to calculate likelihood ratios (LRs) from published allele frequencies. In addition, computer algorithms and biological modeling must be used to infer genotypes from mixed DNA profiles entered into the software system. These capabilities should be optimized to computationally model NGS data and maximize the number of true positives while minimizing false positives.

PHASE I: Develop a prototype expert probabilistic genotyping system that can ingest NGS data from at least one NGS STR and SNP chemistry/platform type. The software must demonstrate the ability to analyze clear two-person mixtures with input from a reference profile for inclusion. A fully continuous approach is required, incorporating biological parameters such as peak height ratio, mixture ratio and stutter. The output file should deconvolute the mixture into potential genotypes, providing weights to each genotype inferred, display sequence information for both contributors, and contain a likelihood ratio for two competing hypotheses using published allele frequencies from a single population. It is highly desirable that the software parameters include population allele frequencies, drop-out, drop-in, stutter, and kit variance. Ideally, these parameters will be customizable to allow laboratories to use any NGS STR and SNP technology available. Design of the software platform must not prohibit backward compatibility with CE data. Preferably the software platform will run on commercially available computing systems. Ideally at the end of the phase I effort, the analysis of at two-person DNA mixture can be demonstrated in minutes.

PHASE II: Extend the methods and computer algorithms developed in Phase I to allow for ingestion of NGS data from all currently available NGS STR chemistry/platform types. Improve the software system to interpret at least four-person mixtures and low-level DNA samples. Calculate the likelihood ratio for each genotype using allele frequencies from user-selected population groups (typically Caucasian, African American and Asian) in a single run. Establish a training set of samples to evaluate the software system performance. For guidance on testing probabilistic genotyping systems, please refer to the “SWGDAM Guidelines on Validation of Probabilistic Genotyping Systems” [3]. Incorporate the developed methods and computer algorithms into a mature software system with a user-friendly interface and the ability to allow integration of data output into case reports. The software must be designed to allow backward compatibility with CE data. Prior to mixture deconvolution, it is highly desirable that the software has the ability to utilize NGS SNP and STR information to infer the number of contributors (NOC). Ideally the analysis of a complex four-person mixture could be completed within hours.

In addition to monthly technical progress reports, deliverables will include: a detailed report demonstrating specifics on how the software obtains its answer (black box systems are unacceptable), a user guide for the software including set-up and troubleshooting, and a report describing the results of the Phase II sample set testing.

PHASE III DUAL USE APPLICATIONS: The development of an expert probabilistic genotyping software system that reliably interprets NGS data using a fully continuous approach will have a significant impact in the forensic science community at the federal, state and local levels. The software will fully utilize the sequence information that NGS affords, allowing for the objective and reliable interpretation of more complex DNA mixtures than is possible with capillary electrophoresis-based methods. Software developed under this topic will initially be tested and evaluated in Government forensic laboratories to assess applicability within forensic analytical workflows. There are a number of commercial applications for analysis of samples that will directly benefit from this new software capability including: research purposes, law enforcement, and medical diagnostics.

REFERENCES:
1. Butler Gettings, K., Kiesler, K. M., Faith, S. A., Montano, E., Baker, C. H., Young, B. A., Guerrieri, R. A., Vallone, P. M., "Sequence variation of 22 autosomal STR loci detected by next generation sequencing," Forensic Sci. int. Genet, vol. 21, pp. 15-21, 2016.

2. Rockenbauer, E., Hansen, S., Mikkelsen, M., Borsting, C., Morling, N., "Characterization of mutations and sequence variants in the D21S11 locus by next generation sequencing," Forensic Sci. Int. Genet, vol. 8, no. 1, pp. 68-72, 2014.

3. (SWGDAM), Scientific Working Group on DNA Analysis Methods, "SWGDAM Guidelines on Validation of Probabilistic Genotyping Systems," 2015.

KEYWORDS: next-generation sequencing, probabilistic genotyping, fully continuous, forensic DNA analysis

A20-026 TITLE: Graphene-Based Composite EMI Shielding for RF Device Protection

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop a graphene-based composite EMI shielding material capable of replacing metal shielding in IC packages and printed circuit board components.

DESCRIPTION: As soldier electronics and their components operate at faster speeds, smaller size, and in closer confinements a substantial increase in Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) can lead to system failures. This effort supports the FREEDOM ERP as it enables enhanced technologies to protect next generation of highly mobile RF communications for battlefield dominance in the broad bandwidth frequencies X-band (8-12 GHz) to the Ku-band (12-18 GHz). Metal EMI shields in IC packages and printed circuit board components have limitations in poor chemical resistance, oxidation in long term harsh environments, high density, flexibility, and form factor. Current strategies to obtain the desired EMI shields mainly rely on increasing the material's thickness to prolong the EM wave absorption routes or loading large amounts of fillers in order to increase its electrical conductivity [1]. However, these factors inevitably increase the production cost and limit scalability.

Generally, conductive fillers have high aspect ratio and large specific surface area, such as carbon nanofibers (CNF), multi-wall carbon nanotubes (MWCNT), stainless-steel fibers (SSF), and graphene layers offer advantages without the limitations imposed by pure metals. Fillers are preferred because they can be dispersed in lightweight polymers to establish efficient conductive paths in the composites and form sufficient interfaces with the polymer matrices, leading to enhanced electrical conductivity and interfacial polarization that are beneficial to the EMI shielding performance. Among the conductive fillers, graphene has the best conductivity, lowest density, and highest thermal conductivity [2]. Silver and cooper have excellent conductivity but the aging stability of metallic nanostructures is big concern for long term storage of electronics in systems for harsh environments.

The development of graphene filler ink formulation offers a major opportunity for improving the deposition of composite shielding materials. Graphene filler ink materials can be dispensed economically by drop casting or using printing technologies with controlled patterning capabilities leading to new technologies, and applications. The inks can be deposited on substrates by methods such as drop casting, inkjet printing, and aerosol-jet printing [3-5]. A path forward lies in the improvement of ink formulation. Ink formulations rely on factors including selection of flake size, solvents, and surfactants that provide the best combination for direct exfoliation of pristine graphene. Several factors limit achieving the high theoretical conductivity 10exp8 S/cm of graphene, which is 3 orders of magnitude higher than highly conductive metals such as copper. These factors include inter-flake percolation, type of binder that hold the fillers together, and post decomposition by annealing. Also, there is a lack of “pristine” graphene flakes in the market [6] that can be improved. The ultimate goal is to deposit a shielding material with properties that would be capable of replacing metal shielding fully in printed circuits.

PHASE I: The responsive proposal shall develop a shielding material. Identify an ink formulation and description of above mentioned factors (i.e. graphene content, inter-flake percolation, surfactants, selection of ink binder, drying agents, and annealing process for binder decomposition) with a printing approach that forms a composite shield on a substrate. For all solutions the ability to block the greatest amount of incident EMI waves by the deposited shielding material is a driver.

METRICS:
Graphene-based composite material (less than 1mm thick) on Kapton or Mylar substrate:
-Electrical conductivity greater than 100,000 S/m
-Substrate or annealing temperature less than 250°C
-Good flexibility and film adhesion to substrate after manual bending, and no micro cracking.
-EMI shielding efficiency (EMI SE) greater than 50dB across broadband frequencies (8-18 GHz)

During the phase-I the contractor shall report and deliver on the following:
(1) Report on the material selection, process development, challenges, and accomplishments.
(2) Document the method of deposition, and minimum size linewidth achieved.
(3) Characterize the composite structural properties, composition and size of the nanostructures.
(4) Document the binder, surfactants, solvents used including the effects of annealing/sintering temperature or post chemical treatment on the conductivity of the deposited composite.
(5) Conduct EMI shielding efficiency studies, record the scattering parameters using a vector analyzer with two port measurement techniques or an equivalent method in the frequency range 8-18 GHz to validate performance claims.
(6) Delivery of deposited material samples on Mylar or Kapton substrate with pattern size 0.5"x1.5" for validation:
(a) Deposition single layer of uniform film on sample as a baseline. Include data of the measured film uniformity, roughness, thickness, resistivity, conductivity, and EMI SE.
(b) Deposition multiple layers (up to a maximum total thickness of 1mm) that demonstrates best achieved conductivity and EMI SE. Include data of the measured film uniformity, roughness, thickness, resistivity, conductivity, and EMI SE.
(7) Propose improvements for phase-2, challenges, solutions, and applications.

PHASE II: This phase addresses a current needs relevant to the US military: a lightweight and durable EMI shield on IC packages and printed circuit boards components that protect against radio frequency interference (RFI). Develop a scale-up demonstration/validation program, on an application relevant to the US military based upon the previous phase I requirements and on-going proprietary developments.

METRICS:
-Ability to the composite film adhere to variety of electronic substrates and packaging (Mylar, Kapton, Si, SiO_2, glass, ceramic, paper), determine the limitations.
-Repeatability of printing square shield patterns (1 mm, 1 cm, 5 cm, 10cm), determine the limitations.
-Reliability of formulated solution for printing without clogging the printing head, determine the number of cycles.
-Storage of ink formulation beyond 3 months without observable segregation and settling, determine the maximum time within contract period.
-Stability of composite film at mil specification temperatures -65 degrees F to 165 degrees F.

This phase is intended produce a full scale 3D prototype EM shielding. The full scale system will also address key factors in maintaining an effective shield, such as conformal coating that allows for continuity of conductivity over integrated circuits. The main technical objectives:
(1) Demonstrate/validate a system that is capable of repetitive or continuously coating.
(2) Fabricate a full-scale 3D prototype of the shielding on IC's and PCB components.
(3) Validate that the EMI shielding performance meets the specified requirements.

PHASE III DUAL USE APPLICATIONS: Implement a business case and partner with a DOD supply chain to commercialize the EMI shielding material system to a TRL 7 System prototype demonstration in field environment. We envision use of shielding in military applications such as solider radios, prognostics/diagnostics, unmanned air vehicles (UAV's), drones, unattended ground sensors, security access/entry, RF ID tags, and air defense systems. For commercial applications in cell phones, computers, and medical equipment.

REFERENCES:
1. M. Verma, et al. "Graphene nanoplatelets/carbon nanotubes/polyurethane composites as efficient shield," Composites Part B 120 (2017) 118. http://dx.doi.org/10.1016/j.compositesb.2017.03.068

2. https://en.wikipedia.org/wiki/Graphene#Electronic

3. T.S. Tran et al. "Graphene inks for printed flexible electronic," Advances in Colloid and Interface Science 261 (2018) 41-61. https://doi.org/10.1016/j.cis.2018.09.003

4. G. Hu et al. "Functional inks and printing of two-dimensional materials," Chem. Soc. Rev. (2018) 47, 3265-3300. https://doi.org/10.1039/c8cs00084k

5. M. A. Monne et al. “Proc. SPIE 10725, Low-Dimensional Materials and Devices” (2018). http://dx.doi.org/10.1117/12.2323546

6. Kauling, et al. “The Worldwide Graphene Flake Production,” Adv. Mater. (2018) 30, 1803784. http://dx.doi.org/10.1016/j.cis.2018.09.003

KEYWORDS: Shielding, Electromagnetic interference (EMI),Radio Frequency (RF),Flexible Shielding effectiveness (SE)
Conformal

A20-027 TITLE: Advanced Ceramic Matrix Composite Gas Turbine Engine Research Combustor

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Explore, fabricate and evaluate ceramic matrix composite combustor research prototype for gas turbine engine and other air breathing propulsion applications, using advanced innovative design and manufacturing methods, to identify and mitigate SiC-SiC ceramic matrix composite materials and manufacturing vulnerabilities for CMC combustor operating in austere environments.

DESCRIPTION: To meet the demands of current and future requirements, military gas turbine engines (GTEs) are required to operate at ever higher temperatures. Current engine temperatures can exceed 1500 °C, with future engines projected to exceed 2000 °C. Implementation of Silicon Carbide (SiC-SiC) ceramic matrix composite (CMCs) components including CMC combustor in propulsion engines of interest to the US Army is now a tangible reality, representing the most fundamental change in design and manufacturing practices for gas turbine engines since the introduction of single-crystal superalloys [1]. Advanced CMCs offer significant advantages over the current set of superalloy-based systems, but these materials can be brittle and will degrade over time, due to high temperature creep, thermal shock and cyclic thermomechanical loads. Specific innovation research focus areas include increased thermomechanical durability, increased resistance to environmental interactions, cost-effectiveness of processing and manufacturing, and improved approaches to CMC combustor component fabrication and integration. Computational tools and integrated experimental/computational methods are sought, including models/tools to predict degradation and failure mechanisms within CMC combustor.

Application of SiC-based CMCs in combustion environments for gas turbine engine combustors operating at 1310° C or higher require significant scientific advancement in the SiC-SiC CMC material system. Unfortunately, exposures of these materials to high temperature combustion environments limit the effectiveness of thermally grown silica scales in providing protection from oxidation and component recession during service. The nature of the SiC based ceramic recession issue dictates that the combustor material system must provide prime reliant performance to ensure full component lifetime [1-13]. Thus the CMC combustor requires SiC-SiC bulk material system with improved state of the art thermal/environmental barrier coatings (EBCs) for limiting oxygen/water vapor transport, and high temperature phase stability, integration with metallic engine components mitigating thermal coefficient of expansion mismatch and optimized effusion combustion liner holes.

PHASE I: Research and formulate innovative CMC combustor analysis and design methods leading to the development of affordable, high speed with high throughput manufacturing of SiC-SiC ceramic matrix composite materials for gas turbine combustors. Beyond a combination or standalone SiC-SiC manufacturing methods such as conventional chemical vapor deposition, pyrolysis infiltration process, and melt infiltration process, explore advanced manufacturing processes of CMC components including additive manufacturing methods and Field Assisted Sintering Technologies (FAST). Perform combined computational fluid dynamics and computation structural dynamics modeling and high fidelity simulation of CMC combustor concepts under combined effects of aerodynamic, thermal, combustion chemical reactance and structural loads. Using the proposed advanced manufacturing processes and preliminary design, fabricate at least three prototype curved CMC specimens with embedded impingement holes and thermal/environmental barrier coating and subject to at least 20 hot/cold two hour duration thermal cycles of steady-state combustion flame temperature of 1482 deg Celsius or higher to identify potential CMC material vulnerabilities at combustion temperatures. Post-test material characterization of the CMC curved specimens will be performed to identify any manufacturing defects and material degradation due to thermal cycling. Prototype ceramic matrix composite coupons will be delivered to CCDC Army Research Laboratory (ARL) for high temperature strength testing, fluid flow characterization, and microstructure analysis. A preliminary research grade CMC combustor analysis and design shall be conceived and delivered to CCDC – ARL at the end of Phase I.

PHASE II: Explore, develop and validate the innovative SiC-SiC CMC research combustor using design and fabrication approaches of Phase I. Partnership with an Original Equipment Manufacturer (OEM) of gas turbine engine is encouraged. The proposer shall conduct high fidelity modeling and design analysis of the research grade CMC combustor prototype (e.g. representative medium lift rotorcraft turboshaft engine combustor prototype) including computational thermal fluid structural analysis with conjugate heat transfer methods to develop the combustor pattern factor and identify potential hotspot and highly stressed zones. Explore innovative methods for SiC-SiC CMC component integration with hot metal superalloys and advanced manufacturing of optimized embedded impingement and effusion holes within the combustor liners with thermal/environmental barrier coatings. Fully instrumented jet burner rig ground based experimental tests need to be conducted on the CMC combustors at CCDC-ARL Hot Particulate Ingestion Rig (HPIR) or another federal government or industry test facility subject to thermal cycling of at least 100 hot/cold two hour duration thermal cycles of steady-state flame temperature of 1550 deg Celsius or higher to identify CMC combustor material state vulnerabilities at engine relevant austere environment and explore possible mitigation solutions. The proposer shall perform pre and post experimental test nondestructive evaluation of the CMC combustor and post-test material characterization of the CMC combustor material system to explore and identify embedded defects including fiber and matrix cracks, identify zones of SiC fiber agglomeration, SiC matrix silica pools, large void spaces within the CMC substrate, and durable interphase materials. The proposer will research methods to alleviate the aforementioned possible defects in CMC combustor material system. Additionally, ceramic matrix composite combustor prototype(s) will be delivered to the CCDC - ARL for further full field high temperature characterization and research development including CMC microstructure analysis and further enhancement.

PHASE III DUAL USE APPLICATIONS: The proposer will partner with an Engine OEM and conduct validation testing including full scale engine ground testing. The CMC combustor technology can be transitioned as prototype CMC combustor for a medium size rotorcraft turboshaft engine to PM Advanced Turbine Engine, PEO Aviation, Huntsville and CCDC – Aviation and Missile Center at Corpus Christi, TX. The end result of this research effort will be a validated approach for development of CMC Combustor transitioned to medium size future vertical aircraft propulsion system.

REFERENCES:
1. Ghoshal, A., Murugan M., Nieto, A., Walock, M. J. et al, "High Temperature Ceramic Matrix Composite Materials Research for Next Generation Army Propulsion System"

2. M. H. Vidal-Setif, N. Chellah, C. Rio, C. Sanchez, and O. Lavigne, "Calcium–magnesium–alumino-silicate (CMAS) degradation of EB-PVD thermal barrier coatings: Characterization of CMAS damage on ex-service high pressure blade TBCs," Surface and Coatings Technology, vol. 208, pp. 39-45, 2012/09/15/ 2012.

3. J. L. Smialek, N. S. Jacobson, B. Gleeson, D. B. Hovis, and A. H. Heuer, "Oxygen permeability and grain-boundary diffusion applied to alumina scales," National Aeronautics and Space Administration, Glenn Research Center TM-2013-217855, 2013.

4. B. J. Harder, J. Ramìrez-Rico, J. D. Almer, K. N. Lee, and K. T. Faber, "Chemical and Mechanical Consequences of Environmental Barrier Coating Exposure to Calcium–Magnesium–Aluminosilicate," Journal of the American Ceramic Society, vol. 94, pp. s178-s185, 2011.

5. K. N. Lee, D. S. Fox, and N. P. Bansal, "Rare earth silicate environmental barrier coatings for SiC/SiC composites and Si3N4 ceramics," Journal of the European Ceramic Society, vol. 25, pp. 1705-1715, 2005/01/01/ 2005.

6. N. L. Ahlborg and D. Zhu, "Calcium–magnesium aluminosilicate (CMAS) reactions and degradation mechanisms of advanced environmental barrier coatings," Surface and Coatings Technology, vol. 237, pp. 79-87, 2013/12/25/ 2013.

7. S. Ramasamy, S. N. Tewari, K. N. Lee, R. T. Bhatt, and D. S. Fox, "Mullite–gadolinium silicate environmental barrier coatings for melt infiltrated SiC/SiC composites," Surface and Coatings Technology, vol. 205, pp. 3578-3581, 2011/03/15/ 2011.

8. K. N. Lee, "Key Durability Issues With Mullite-Based Environmental Barrier Coatings for Si-Based Ceramics," Journal of Engineering for Gas Turbines and Power, vol. 122, pp. 632-636, 2000.

9. R. T. Bhatt, S. R. Choi, L. M. Cosgriff, D. S. Fox, and K. N. Lee, "Impact resistance of environmental barrier coated SiC/SiC composites," Materials Science and Engineering: A, vol. 476, pp. 8-19, 2008/03/15/ 2008.

10. Faucett, D.C. and S.R. Choi. Strength Degradation of Oxide/Oxide and SiC/SiC Ceramic Matrix Composites in CMAS and CMAS/Salt Exposures. in ASME Turbo Expo 2011. 2011. Vancouver, British Columbia, Canada: ASME.

11. Xu, Y., Hu, X., Xu, F., Li, K., "Rare earth silicate environmental barrier coatings: Present status and prospective", Ceramics International, Vol. 43, 2017, pp. 5847-5855

12. Richards, B.T., Young, K.A., Francqueville, F, Sehr, S., Begley, M.R., Wadley, H.N.G., "Response of ytterbium disilicate-silicon environmental barrier coatings to thermal cycling in water vapor", Acta Materialia, Vol. 106, 2016, pp. 1-14.

13. Appleby, M.P., Zhu, D., Morscher, G.N., (2015) Mechanical properties and real-time damage evaluations of environmental barrier coated SiC/SiC CMCs subjected to tensile loading under thermal gradients, Surface & Coatings Technology, Vol. 284, pp. 318-326.

KEYWORDS: Ceramic Matrix Composite Materials, SiC-SiC (Silicon Carbide - Silicon Carbide), CMC combustor design, interphase layer, Jet Burner Rig Test.

A20-028 TITLE: On-Site Formate Production

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Develop and demonstrate methods to enable distributed production of potassium formate.

DESCRIPTION: The ability to manufacture materials near their point of use is a priority for the crosscutting Sustain and Train Cross Functional Team (CFT) in the Army Modernization Priorities. For example, chemical deicing represents about one-third of winter maintenance expenditures for bases and municipalities. Currently sodium chloride is often used to deice road surfaces despite concerns about corrosivity, to both motor vehicles and infrastructure, and environmental impact including vegetation damage through chloride uptake, soil damage through sodium accumulation, and drinking water contamination. This effort seeks the development of methods for onsite production using waste carbon dioxide from point source at moderate conditions (low pressure and temperature) on posts/bases of potassium formate which is an environmentally friendly/low corrosion deicing material (reference 2). Recent results show that electrochemical reduction of carbon dioxide to form formates is possible. This approach could enable systems that utilize inexpensive and readily available materials and would economically produce potassium formate in a form readily usable for roadway and runway deicing.

PHASE I: Explore catalysts and processes to electrochemically reduce carbon dioxide to produce formate under moderate conditions. Characterize system efficiency and byproducts as a function of reaction conditions to achieve >75% process efficiency. Provide 5 lbs of formate generated using the laboratory system. Determine system degradation mechanisms to enable system life of >8000 hours. Demonstrate at laboratory scale a system capable of producing potassium formate under moderate conditions (<100 psi, and <100 degrees Celsius), Prepare analysis of cost/pound of formate focusing on the use of nonflammable, inexpensive, readily available starting materials.

Estimate scaled up production costs.

PHASE II: Continue process/catalyst optimization. Build and deliver a system capable of generating 20 lbs/day of potassium formate under moderate conditions using waste carbon dioxide and low cost/readily available materials in a cost effective manner. Demonstrate operation of the system for a minimum of 5 days, generating 100 lbs of material. Determine and optimize operation costs and system efficiency which should be >85%. Ideally the system will be capable of utilizing intermittently renewable energy sources. Goal should be to achieve production cost including cost of starting materials of <$800/ton of potassium formate.

PHASE III DUAL USE APPLICATIONS: Build a system capable to producing 100s of lbs/day of potassium formate using renewable energy sources under moderate conditions that uses safe, readily available, and inexpensive starting materials. Goal should be to achieve production cost <$800/ton of potassium formate. This system could be used on posts/bases or municipalities and airports for roadway and runway deicing and reduce corrosion and environmental impact associated with road salt.

REFERENCES:
1. P. Kang; S. Zhang; T. J. Meyer; M. Brookhart, Rapid Selective Electrocatalytic Reduction of Carbon Dioxide to Formate by an Iridium Pincer Catalyst Immobilized on Carbon Nanotube Electrodes. Angew. Chem. Int. Edit. 2014. 53 (33), 8709-8713.

2. Pasi P. Hellst'n, Jani M. Salminen, Kirsten S. JÃ¸rgensen, and Taina H. NystÃ©n (2005). "Use of potassium formate in road winter deicing can reduce groundwater deterioration." Environ. Sci. Technol. 39 (13): 5095â€“5100. doi:10.1021/es0482738. PMID 16053115

3. A process (ii) for making potassium formate WO 1996001249 A1

4. P. Kang; C. Cheng; Z. F. Chen; C. K. Schauer; T. J. Meyer; M. Brookhart, Selective Electrocatalytic Reduction of CO2 to Formate by Water-Stable Iridium Dihydride Pincer Complexes. J. Am. Chem. Soc. 2012. 134 (12), 5500-5503

5. Opportunities and prospects in the chemical recycling of carbon dioxide to fuels. (2009, December 30). Retrieved from http://www.sciencedirect.com/science/article/pii/S0920586109004416

6. Catalysis of the electrochemical reduction of carbon dioxide. (2012, December 11). Retrieved from http://pubs.rsc.org/en/content/articlehtml/2013/cs/c2cs35360a

7. Electrocatalytic Process of CO Selectivity in Electrochemical Reduction of CO2 at Metal Electrodes in Aqueous Media. (1993, September 15). Retrieved from http://www.sciencedirect.com/science/article/pii/0013468694851727

KEYWORDS: potassium formate, deicing, on-site production, manufacturing at point of need

A20-029 TITLE: Non-Intrusive Pressure Measurement in Cannon Gun Tubes

TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Develop an innovative, remote sensor technology for measuring peak pressure and dynamic pressure differentials inside large caliber gun tubes.

DESCRIPTION: For propellant engineers and internal ballisticians, accurate measurement of internal cannon pressures (during a firing event) is crucial for research and development purposes. Of special importance are the measurement of the peak pressure in the chamber and the calculation of differential pressure [1] (the difference in pressure between two points) across the chamber section of cannon gun tubes.

Currently, internal chamber pressure is measured using piezoelectric transducers [2]. The transducers are installed such that the piezoelectric sensor is exposed to the internal volume of the chamber, thus requiring the gun tube and/or breech assembly to be drilled and tapped. Ballistic pressure data is recorded at high frequency (>250 Hz) and plotted to form Pressure vs Time Graphs. For prototype weapons, it may be impractical to drill the gun tube to accommodate traditional pressure gages. This topic seeks an innovative solution for collecting internal ballistic pressure data, without modifying the system under test.

The measurement of the peak pressure in the chamber and the calculation of differential pressure may be achieved by one application of the remote sensor technology or by two different applications/methods.

The system developed under this effort must meet the following key system attributes (KSAs):

Pressure Range: 0 – 150kPsi
Sampling Frequency: = 250 Hz
Resolution: = 0.5%
Temperature Range: 0 – 3,600 °F
Ability to withstand explosive shock and high G-forces resulting from explosive charge detonations
Robust design capable of surviving impacts by foreign materials during detonations

PHASE I: Evaluate novel applications of advanced pressure sensor materials and data acquisition technologies for use in a ballistic environment. Desired outcomes; Design a concept for remote monitoring of internal pressures, with the potential to meet the KSAs, without requiring any modification to the gun tube (e.g., drilling a hole), further refine the KSAs and conduct an analysis of alternatives to select the best combination of materials and data acquisition technologies for prototypes to be delivered in Phase II.

PHASE II: Subject the most promising material solutions (identified in Phase I) to testing, simulating live fire conditions. Desired outcomes; Produce at least one prototype using the selected sensor / data acquisition system combination, subject the "as manufactured" prototype to simulated firing conditions to assess performance against the KSAs and perform final design refinements. Document the final solution and manufacturing process in the form of a technical data package. TRL: (Technology Readiness Level) TRL Explanation Biomedical TRL Explanation TRL 6 - System/subsystem model or prototype demonstration in a relevant environment.

PHASE III DUAL USE APPLICATIONS: Conduct a live fire demonstration of the final prototype in an operational environment with participants from various U.S. Government agencies and contractors from the weapons and defense industry. Explore potential applications for both military and private sector customers. This technology could be used for monitoring pressure vessels, steam turbines, oil & gas pipelines, and aerospace applications.

REFERENCES:
1. ASTM F2070-00(2017), Standard Specification for Transducers, Pressure and Differential, Pressure, Electrical and Fiber-Optic, ASTM International, West Conshohocken, PA, 2017, www.astm.org

2. PCB Group, Inc. "Ballistic Pressure Sensors Reference Guide." PCB Piezotronics, 2014, www.pcb.com/contentstore/MktgContent/LinkedDocuments/Aerospace/BallisticPressureGuide.pdf

KEYWORDS: pressure, differential, transducers, artillery, cannon, chamber

A20-030 TITLE: Independent Gun Location and Gun Tube Pointing Device

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Design and build a system that can remotely and independently determine the location of a howitzer and the orientation (azimuth and elevation) of the gun tube, display the position and pointing data, in real time to a terminal/monitor at the control center and other remote locations located as far as 25 km.

DESCRIPTION: During certain types of large caliber firing tests, the weapon pointing is done automatically by the system under test and or by the system operators. The tactical nature of these events makes it very difficult to perform an independent verification of the gun tube pointing prior to firing. There is a need, from a range safety standpoint to verify the location of the howitzer and orientation of the gun tube during such events to ensure weapons are fired within the established safety corridors. A system is required that is portable/mobile/deployable and operates independent of the weapon platform. The system then needs to be able to determine and transmit the location and pointing data to a control center and other remote locations which may be located as far as 25 km away. The data must be transmitted in real time and must consist of weapon location, gun tube horizontal angular measurement and a gun tube vertical angular measurement. The system must enable the user to input custom maps for graphical display purposes. At the control center and the remote locations, the terminal or display must numerically and graphically display the data in real time. The reference azimuth for the angular measurements must be user selectable (i.e. azimuth with respect to true north, geodetic north, etc.)

The system developed under this effort must meet the following performance goals:

Vehicle location accuracy: ± 1 meter
Gun tube azimuth accuracy: ± .1 degree
Gun tube elevation accuracy: ± .2 degrees
Rugged & mobile:

- Temperatures from -40 to +140°F
- Water and dust proof
- Deployable in rough desert terrain, portable via pickup truck or similar and self contained.

PHASE I: Perform a feasibility study in support of the development of a Remote gun location and Gun tube pointing determination system which meets the specification above. Evaluate innovative technologies which may be used to build, integrate the system and leverage existing technologies. Perform trade-off analysis to determine the best approach for howitzer location and gun pointing determination system, and develop a preliminary design for the system.

PHASE II: Develop a prototype system. Demonstrate the system technology and characterize its performance.

PHASE III DUAL USE APPLICATIONS: The system developed under this topic could be used by other test and training ranges to increase safety when firing large caliber weapons. The system could also be marketed to foreign militaries for use on their training and test ranges.

REFERENCES:
1. Army AL&T magazine

2. Field Manual 3-09.8 Field Artillery Gunnery

3. Field Manual 6-40 Tactics, Techniques, and Procedures for Field Artillery Manual Cannon Gunnery

4. Technical Manual 9-2350-314-10, Operator's Manual, Howitzer, Medium, Self-Propelled: 155MM, M109A6

KEYWORDS: artillery, fire control, quadrant elevation, azimuth of fire, range safety

A20-031 TITLE: Soft Catch System for Large Caliber Ammunition

TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Design and build a system that can stop large caliber ammunition with minimal damage to the external and internal features and components.

DESCRIPTION: During various phases of large caliber ammunition development, there is a requirement to assess internal ballistics, strength of design, and function of critical components, requiring a need to perform "soft catch" testing, where the munition can be fired at operational velocities, and captured in a way that does not damage the projectile. This is often needed to assess the performance of munition behavior during setback and the effect on fuze function, or that subcomponents (such as deployable fins) survive firing and launch. Current soft catch methodologies use hay, water, sand, and ballistic gelatin. Although there has been a limited level of success using these methodologies, a significant portion of test munitions are damaged during firing and recovery, which requires additional testing and prototype munitions, causing a medium risk to systems under test, due to increased cost and timelines. The system developed under this effort must be able to consistently catch large caliber ammunition regardless of the features and fill such as pyrophoric white phosphorus, high explosive agents, sensor heads and other electronics, deployable aerodynamic features, submunitions, and depleted uranium (DU) penetrators with minimal damage to munition's external and internal features.

The system developed under this effort must meet the following performance specifications:

Stop munitions up to 400 lbs
Stop munitions up to 16" in diameter
Stop munitions with kinetic energies of 20 MJ at a minimum
Must be able to catch and recover up to 10 munitions in a 10 hour period
Rugged:
- Temperatures from -40 to +140°F
- Water and dust proof

PHASE I: Perform a feasibility study in support of the development of a soft catch system for large caliber ammunition which meets the specifications above. Evaluate innovative technologies which may be used to build, integrate the system and leverage existing technologies. Perform trade-off analysis to determine the best approach to the soft catch system, and develop a preliminary design for the system.
Metrics:
Develop a model of concept design with detailed analysis and predicted performance.
Provide modeling and simulation analysis on key components along with limiting factors of the materials to be used.

PHASE II: Develop a prototype system. Demonstrate the system technology and characterize its performance.
Metrics:
design and develop a prototype based on Phase 1 modeling.
Prototype must be able to:
Stop munitions up to 400 lbs
Stop munitions up to 16" in diameter
Stop munitions with kinetic energies of 20 MJ at a minimum
Must be able to catch and recover up to 10 munitions in a 10 hour period

PHASE III DUAL USE APPLICATIONS: The system developed under this topic could be used by other test and training ranges to increase safety and reliability when firing and recovering large caliber ammunition. The system could also be marketed to foreign militaries for use on their training and test ranges.

REFERENCES:
1. Technical Manual 43-0001-28, Army Ammunition Data Sheets

KEYWORDS: artillery, large caliber, soft catch, recovery, internal ballistics

A20-032 TITLE: Laser Site Propagation Turbulence Profiling and Forecasting

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate a system for turbulence profiling from a laser ground station for propagation to ground, air, and space targets given real-time optical measurements with integrated forecasting capabilities.

DESCRIPTION: The propagation of laser sources through the atmosphere from a ground site is affected considerably by atmospheric turbulence conditions surrounding the laser transmitter, in addition to turbulence conditions aloft. Turbulence conditions are affected by prevailing meteorological conditions in addition to local topography for the laser operating site, or at the target if located on the ground. For airborne targets, the turbulence conditions depend on the drop-off of turbulence with altitude near the ground and wind-shear conditions aloft. Propagation to space targets may involve long paths where inhomogeneous conditions exist over a range of altitudes. For laser propagation paths to ground, air, and space targets, the turbulence profile will determine the properties of atmospheric effects on laser illumination, and the ability to correct of an atmospheric channel with adaptive optics (AO) compensation systems. A system is desired for measuring existing turbulence conditions in the volume surrounding a laser installation site, as well as forecasting turbulence conditions at later times. The system may involve auxiliary sources, sensors, and platforms which work cooperatively with the ground station for turbulence profiling.

PHASE I: Develop new approach or employ existing techniques for turbulence profiling from a ground site to ground, air, and space targets. Quantify the capabilities of the turbulence profiling method through numerical simulations. Illustrate how the measurements may be used to aid turbulence forecasting capabilities. Develop a preliminary design for field testing to be conducted during Phase II.

PHASE II: Using the results from Phase I, develop prototype turbulence profiling hardware for use in field testing. Conduct field tests for ground and air targets out to 10 km range. Devise methods to extend operation ranges for space targets. Demonstrate the turbulence profiling and forecasting capability through field testing at an appropriate laser operating location.

PHASE III DUAL USE APPLICATIONS: Military laser systems operating at ground sites will be provided environmental turbulence conditions for assessing performance limitations. Optical communication systems may be environmentally adapted for optimized performance given measured or forecast turbulence conditions.

REFERENCES:
1. T.C. Farrell, D.J. Sanchez, P. Kelly, A. Gallegos, W. Gibson, D. Oesch, E.J. Aglubat, A.W. Duchane, D.F. Spendel, T. Brennan, “Characterizing Earth’s Boundary Layer (CEBL),” Proc. OSA, Propagation Through and Characterization of Distributed Volume Turbulence (2014).

2. D.H. Tofsted, “Modeling Turbulence Generation in the Atmospheric Surface and Boundary Layers,” U.S. Army Research Laboratory report, ARL-TR-7503 (2015).

KEYWORDS: communication, lasers, meteorology, sensing

A20-033 TITLE: Application of Artificial Intelligence/ Machine Learning/Deep Learning to the Test and

Evaluation of Command, Control, Communication and Intelligence (C3I) systems

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Design and create a tool that automates and optimizes planning and test execution of Artificial Intelligence/ Machine Learning/Deep Learning enabled Command, Control, Communication and Intelligence (C3I) network and systems.

DESCRIPTION: Recent advances in the areas of artificial intelligence/ machine learning/deep learning (AI/ML/DL) have provided the opportunity to automate time-consuming manual processes in C3I network Test and Evaluations (T&E). Specifically, the incorporation of such things as neural networks and training processes has elevated AI/ML/DL as key innovation areas to improve test planning and reduce validation/verification of test infrastructure prior to test execution. This effort would mature these AI/ML/DL concepts to develop a planning/execution tool to generate a location specific network (system under test) architecture recommendations (based upon number of nodes, topography, Radio Frequency propagation, number of communication hops, etc.). Node locations will ensure that testing of the performance edges are verified (e.g. number of communications hops is selectable 1 – N drives node location). Additionally, this tool will recommend an optimal data collection infrastructure, perform the data collection, analysis and presentation. Real-time performance monitoring, analysis and feedback during test operations will enable improvements to the data collection and test processes. The collected dataset(s) will provide inputs to the AI/ML/DL tool enabling learning and improvement of tool functionality over time. The tool will also provide root-cause analysis for anomalies identified during test, improving use case implementation and execution. The system would follow a Modular, Open Systems Approach (MOSA) to allow T&E of a variety of Army systems. The MOSA approach would also provide extensible AI/DL/ML functions to identify and expand upon critical characteristics of the C3I systems. This tool will enable non-deterministic approach to C3I T&E. This tool must also provide C3I T&E community results expressed in statistical terms for comparison to historical C3I systems performance. Expected uses of the tool outputs are:

Descriptive analysis - data aggregation/mining provides insight into what has occurred
Predictive analysis – statistical models/forecasting to understand what may occur
Prescriptive analysis – optimization/simulation provides course of action recommendation
Note: Model validation, learnability, algorithm efficiency and empathy are among the key features of this tool.

PHASE I: Develop a tool design that includes artificial intelligence (AI) machine learning (ML), and deep learning (DL) algorithms and concepts, hardware and software specifications, and protocol operation (both internal and external).

PHASE II: Develop and demonstrate a prototype artificial intelligence (AI) machine learning (ML), and deep learning (DL) tool in a realistic environment. Conduct testing to prove feasibility over extended operating conditions.

PHASE III DUAL USE APPLICATIONS: End-state of this effort is transition of this tool to military Command, Control, Communication and Intelligence (C3I) programs of record and the commercial market. This tool is envisioned to optimize incorporation and application of artificial intelligence (AI) machine learning (ML), and deep learning (DL) capabilities in the decision-making process. This will provide verification and validation of AI/ML/DL algorithms and confidence in the increasing independent autonomy of Command, Control, Communication and Intelligence (C3I) systems.
DUAL-USE APPLICATIONS: This system could be used in a broad range of military and civilian Command, Control, Communication and Intelligence (C3I) applications where equipment and systems must be optimally located - for example, in military exercises/operations or in enhancing critical industrial/commercial operations in congested/convoluted topographical environments.

REFERENCES:
1. "SUMMARY OF THE 2018 DEPARTMENT OF DEFENSE ARTIFICIAL INTELLIGENCE STRATEGY: Harnessing AI to Advance Our Security and Prosperity". February 12, 2019. Online at https://media.defense.gov/2019/Feb/12/2002088963/-1/-1/1/SUMMARY-OF-DOD-AI-STRATEGY.PDF

2. Pandey, 2nd Lt. Sameer, “Opportunities to use artificial intelligence in Army logistics”. 22 January 2019. Online at https://www.army.mil/article/216389/opportunities_to_use_artificial_intelligence_in_army_logistics

3. CCDC Army Research Laboratory Public Affairs. “Army-funded research boosts memory of AI systems”. May 20, 2019. Online at https://www.army.mil/article/222090/artificial_intelligence_becomes_life_long_learner_with_new_framework

4. Cole, Sally Senior editor, Military Embedded Systems “U.S. Army preps for future of AI on the battlefield”. 1 July 2019. Online at http://mil-embedded.com/articles/u-s-army-preps-for-future-of-ai-on-the-battlefield/

5. US House Armed Serviced Committee. 17 April 2018. “Promoting DOD's Culture of Innovation” Online at https://youtu.be/n6QF7wuMwOo

6. United States Government Accountability Office, Report to the Committee on Science, Space, and Technology, House of Representatives. March 2018. “Technology Assessment: Artificial Intelligence, Emerging Opportunities, Challenges and Implications”. Online at “https://www.gao.gov/assets/700/690910.pdf.

KEYWORDS: Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Test and Evaluation (T&E), Command, Control, Communication and Intelligence (C3I)

A20-034 TITLE: Voice Quality and Call Completion Rate for an Operational Radio Test

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Provide comprehensive call completion rate determination during an operational radio test by obtaining objective measures of the voice quality of each call made. This requires instrumenting radios/operators and automatically grading the voice quality and call completion rate.

DESCRIPTION: This effort requires developing instrumentation to collect the voice traffic; harvest, manage, and correlate the voice data; and automatically determine the quality of the received voice traffic to determine call completion rate. The requirement can be subdivided into the following four areas:

- Voice Collection: The ability to capture all outgoing and incoming voice calls with minimum to no interference with the radio operator. This requires any appended collection capability to have a very small size and weight while having enough power and data storage to not require battery changes or data harvesting within a 96-hour test window. This collection must capture the voice in a manner that is representative of what the Soldier hears. Collecting voice-over IP (VOIP) traffic will not meet this requirement because it does not address the quality of the system under test microphone or speakers which are key components of effective voice quality.

- Voice Data Harvesting and Management: The ability to harvest and manage all collected voice as well as capture key metadata about the voice data (e.g. time collected, location, unit, radio identification, etc.).

- Voice Data Correlation: The ability to correlate all outgoing/sent voice calls with their corresponding received calls. A call is considered a single transmission sent/received pair. The metadata collected must be sufficient to perform this correlation of the voice data files.

- Voice Scoring: The ability to automatically apply a scoring algorithm to compare the sent with received voice data. An example of a scoring algorithm is the OPTICOM Perceptual Objective Listening Quality Analysis algorithm. The voice scoring algorithm must be adjustable to allow for calibration to a user-determined acceptable level. This would be done by conducting a manual voice quality test and comparing the manual scoring to the automated scoring algorithm result. From this comparison, a pass or fail value would be determined and the voice scoring algorithm would be calibrated to that user-determined acceptable level.

Finally, the system will need to generate reports showing call origination and reception over time and call-completion rates over time based on the pass/fail value provided.

PHASE I: Develop a concept for a prototype voice collection capability and present how it will be capable of meeting size, weight, and power constraints in an operational environment. Develop a design for voice data harvesting, management, and correlation to allow for voice scoring. Demonstrate a voice scoring algorithm using government-supplied sent/received voice traffic.

PHASE II: Develop and demonstrate a prototype voice collection capability. Develop a prototype voice data harvesting, management, and correlation capability to allow for voice scoring. Implement a prototype voice scoring algorithm and reporting capability.

PHASE III DUAL USE APPLICATIONS: The end-state of this effort will be to transition and mature this research and prototype capability to deployable test instrumentation for evaluating voice communications during operational testing of new tactical radio systems (e.g. Leader Radio, Manpack).

Commercial applications: Conducting voice assessment of customer service call center agents to verify they can be easily understood. Automated assessment of students learning to speak a new language.

REFERENCES:
1. Beerends, John & Schmidmer, Christian & Berger, Jens & Obermann, Matthias & Ullmann, Raphael & Pomy, Joachim & Keyhl, Michael. (2013). Perceptual Objective Listening Quality Assessment (POLQA), The Third Generation ITU-T Standard for End-to-End Speech Quality Measurement Part I-Temporal Alignment. AES: Journal of the Audio Engineering Society. 61. 366-384.

2. U.S. Army, Program Executive Office Command Control Communications-Tactical, Handheld, Manpack and Small-form Fit, https://peoc3t.army.mil/tr/hms.php

3. HEADQUARTERS, DEPARTMENT OF THE ARMY, TECHNIQUES FOR TACTICAL RADIO OPERATIONS, January 2016, https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/ARN3871_ATP%206-02.53%20FINAL%20WEB.pdf

KEYWORDS: voice collection, voice scoring, Call Completion Rate, radio, Operational Test, Voice correlation

A20-035 TITLE: High Energy, High Power 5V Electrochemical Energy Storage Solution

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: The objective of this topic is to develop an electrochemical cell capable of 5.0 V operation without capacity fade to support high power/energy demand of situational awareness devices in support of the Soldier Lethality Cross Functional Team (CFT).

DESCRIPTION: Lithium-ion batteries are a ubiquitous solution for portable energy storage for military applications. Their high energy density and recharge-ability at a reasonable cost make them very attractive for use in portable systems such as the centralized power source on the Next Generation Squad Weapon or on the Warfighter to enable the Integrated Visual Augmentation System. However, this chemistry is presently limited to lower voltage operation due to the voltage stability of the cell-level components. Traditional lithium-ion batteries utilize carbonate-based organic electrolytes that degrade at elevated voltages above 4.4 V that result in CO¬2 generation, increased cell impedance, and active material consumption which prevent longevity of the cell. Other liquid electrolyte systems with high voltage stability often fail to achieve a suitable anode SEI (solid electrolyte interphase) to allow for continued cycling without capacity fade. In addition to electrolyte limitations, because selected anode potentials are often already close to the potential of lithium, the voltage of the cell is primarily dictated by cathode potential. Therefore, selection of a suitable cathode is critical to achieving the high voltage targeted by this topic. The C5ISR Center is interested in a cell system of electrolyte and electrodes that yield a high energy, high power 5 V electrochemical energy storage solution. Such a solution will directly apply to Soldier

Lethality systems but can be leveraged to meet the demands of the Integrated Tactical Network, radio batteries, or incorporated into a storage component for pulsed power applications.

The resultant cell chemistry must perform across a wide temperature range between -30°C and 60°C. The cell must target a specific energy density greater than 400 Wh/kg at C/5 rate or 300 Wh/kg at a 5C rate at the cell level in order to achieve high performance at a battery level. Cell chemistry must demonstrate < 2% irreversible loss (on 3rd cycle at C/5) after 1 month of storage fully charged at 55°C. Considerations must be made to optimize cell efficiency to prevent wasteful charging conditions. The resultant cell must achieve 50% of capacity at -20 °C at C/10 rate.

PHASE I: Investigate various electrolyte/electrode systems to optimize the electrochemical performance at operating voltages at or above 5.0 V. Demonstrate high voltage operation with greater than 150 cycles in a laboratory cell and begin testing across a range of temperatures between -30°C and 60°C with emphasis on low temperature performance. Deliver 10 representative laboratory coin or single-layer pouch cells to C5ISR Center for preliminary electrochemical performance testing.

PHASE II: Refine and optimize the cell-level materials selected in Phase I and develop and deliver prototype cylindrical cells or multi-layer pouch cells to meet target performance requirements in the specified temperature range with rate capability outlined in this topic.

PHASE III DUAL USE APPLICATIONS: Transition technology to the U.S. Army for packing into a battery system in appropriate physical and electronic configuration. Integrate this technology into portable military devices that require high energy density power sources. Alternatively, integrate this technology into an energy storage component for pulse power applications.

REFERENCES:

1. Chief of Staff of the Army Priority #1

2. Army Warfighting Challenge #16

3. L. Ma, J. Xia, and J.R. Dahn. "Improving the High Voltage Cycling of Li[Ni0.42Mn0.42Co0.16]O2 (NMC442)/Graphite Pouch Cells Using Electrolyte Additives " J. Electrochem. Soc. 2014 volume 161, issue 14, A2250-A2254

4. M. He, L. Hu, Z Xue, C.C. Su, P. Redfern, L.A. Curtiss, B. Polzin, A. von Cresce, K. Xu, and Z. Zhang. "Fluorinated Electrolytes for 5-V Li-Ion Chemistry: Probing Voltage Stability of Electrolytes with Electrochemical Floating Test" J. Electrochem. Soc. 2015 volume 162, issue 9, A1725-A1729

5. J. Alvarado, M. Schroeder, M. Zhang, O. Borodin, E. Gobrogge, M. Olguin, M. Ding, M. Gobet, S. Greenbaum, Y.S. Meng, and K. Xu. "A carbonate-free, sulfone-based electrolyte for high-voltage Li-ion batteries" Materials Today. Volume 21 Issue 4, May 2018, pp. 341-353

KEYWORDS: Energy storage, high energy, portable power, high power, pulse power, soldier lethality, future vertical lift

A20-036 TITLE: Network Assisted Positioning, Navigation and Timing (PNT) in Low RF Signal Power Environments with Bandwidth Efficient Techniques

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate a Positioning, Navigation and Timing (PNT) capability intended to enable Warfighters operating in low RF signal power environments (under tree canopy, vehicles, buildings, and other RF challenged areas) based on a network assisted techniques and time transfer but minimizes the utilization of the network. The primary goal is maximizing access to the PNT source (acquisition/tracking) in low RF signal environments; secondary goals are anti-jam, precision accuracy, and integrity.

DESCRIPTION: Prior work has developed and demonstrated Network Assisted GPS; however, there is a concern for the appreciable load for the function on the network required to accomplish the function. At the current time, the PNT ecosystem is growing well beyond just GPS with respect to the number of services, technologies, and users. Under this topic, research will be devoted to the services, the aiding data and sources, a means to support efficient data transport, storage of the data at the receiving side, techniques for signal acquisition/tracking, security concerns, and the system approach to resolve the problem. System trades will be conducted. The metrics that will be examined (not exclusive) will be time to first fix (TTFF), carrier to noise levels (characterizing environments in which the technique[s] are found useful), amount of data bytes required to be sent via the network to accomplish acquisition and continued tracking, efficacy of the aiding with respect to the time since the aiding information was last received, and ability to acquire with sparse information/time accuracy. Secondary goals are anti-jam (J/S), precision accuracy including positioning, velocity, and timing (PVT), and integrity (ability to sense a failure). Investigations will be conducted with regard to the integration of this capability with Joint Battle Command-Platform (JBC-P) and Nett Warrior.

PHASE I: Conduct the trades and analyses necessary to determine the functional system approach. Reduce risk in Phase I through prototyping and/or system modeling. Conclude Phase I with the definition of the Phase II system specification.

PHASE II: Develop, build, and demonstrate a system prototype. Initial concentration of the prototype can be to use just a few PNT services; however, the scalability of the system to include multiple PNT services should be proven. Use cases to be demonstrated are dismounted Soldier’s access to PNT services in forested/jungle, residential, urban, and within buildings (required). Additional use cases are the demonstration of anti-jamming, precision accuracy, and integrity (desired).

PHASE III DUAL USE APPLICATIONS: The endstate for this topic is that there is potential to scale and continue to grow and support the entire Army (perhaps DOD) PNT ecosystem. Continued development and refinement, system will be further expanded in function to cover additional use cases and environments. In the commercial domain, similar parallels exist, for instance in the cellular network today where users need PNT access virtually anywhere, and as the PNT ecosystem continues to evolve, this system will need to be flexible to incorporate them.

REFERENCES:
1) “Network Assisted GPS … Coming Soon to a Precision Fire Mission Near You!”, Paul Manz, US Army, PEO Ammunition, https://asc.army.mil/web/news-network-assisted-gps-coming-soon-to-a-precision-fire-mission-near-you/

2) “Urban/Indoor Navigation Using Network Assisted GPS”, Brown, Alison K, Navsys Corporation; Olson, Paul, US Army, CCDC, C5ISR Center, Technical Report, Defense Technical Information Center, https://apps.dtic.mil/dtic/tr/fulltext/u2/a444157.pdf

3) “SPOT in Location Based Emergency Services, LBES Detailed Analysis”, Ali Sarwar, Binghao Li, Andrew G. Dempster, UNSW, Australia, https://www.researchgate.net/profile/Andrew_Dempster2/publication/242781684_SPOT_in_Location_Based_Emer

gency_Services_LBES_Detailed_Analysis/links/00b7d5383cbfaa064b000000/SPOT-in-Location-Based-Emergency-Services-LBES-Detailed-Analysis.pdf

KEYWORDS: Positioning, Navigation and Timing (PNT), Assured Positioning, Navigation and Timing (APNT), Network Assisted PNT, Network Assisted GPS, Global Navigation Satellite System (GNSS) PNT Ecosystem

A20-037 TITLE: Dynamic Frame Rate Throttling for High Resolution Low Light Cameras

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate a Si:CMOS chip that is sensitive to low light applications that demonstrates frame rate throttling based on ambient light level conditions.

DESCRIPTION: Current Si:CMOS low light imaging technology has matured to the point where it is relevant for military missions. However, at the lowest light levels, these sensors still suffer from a lack of photons in the VIS-NIR waveband. For the dismounted Soldier, this can cause a lack of situational awareness in the lowest light conditions (overcast starlight, building interiors, etc.). This topic will address this shortcoming by demonstrating the feasibility of frame rate throttling based on ambient light conditions. Using a Si:CMOS chip that is sensitive to low light conditions, the associated readout integrated circuit (ROIC) should be capable of dynamically changing frame rates based on the amount of available light in order to maximize Signal-to-Noise ratio (SNR) while avoiding saturation. This should support frame rates from 240 Hz down to 15 Hz based on the light level available and be able to throttle in two frame times or less. Solutions that also provide dynamic pixel area aggregation are preferred, but not required. This would have sufficient resolution for situational awareness applications and would be able to fit on a small UAV or be carried on a helmet. These and other potential applications align closely with the Soldier Lethality Army Modernization Priorities.

PHASE I: The vendor shall show technical feasibility through design, modeling, and analysis. The design shall be optimized to operate in low ambient light conditions. Demonstrate a clear path to achieving manufacturability and to meeting small SWAP-C goals.

PHASE II: Produce the ROIC solution designed in Phase I and integrate into prototype imager system. Accompany the imager on at least one field event to observe frame rate throttling performance.

PHASE III DUAL USE APPLICATIONS: Refine product developed in Phase II into a Standards Compliant Low Light Level Camera (SCL3C)-type module for integration into military applications. Military applications can include dismounted Soldier and autonomous vehicle mobility. This topic supports SL (e.g., IVAS/Digital Soldier, SBS, Smart Sight, ENVG-B), NGCV (e.g., OMFV, RCV), and FVL (e.g., FARA). Nonmilitary commercialization opportunities would include autonomous navigation and integration into scientific CMOS imaging systems.

REFERENCES:
1. Choi, B.-S, et al. (2017). A Low-power CMOS Image Sensor Based on Variable Frame Rate Operation. Journal of Semiconductor Technology and Science. 17. 854-961.

2. Choi, Jaehyuk, et al. (2007). A Spatial-Temporal Multi-Resolution CMOS Image Sensor with Adaptive Frame Rates for Moving Objects in the Region-of-Interest. 502 - 618.

3. Chuang, K. (2016). Dynamic Frame Rate: A Study on Viewer Perception of Changes in Frame Rate within an Animated Movie Sequence. ACM SIGGRAPH 2016 Posters, 81.

KEYWORDS: LLL, low light level, imaging, camera, ROIC, frame rate

A20-038 TITLE: Cyber Terrain and Electromagnetic Operating Environment (EMOE) Scenario Generation Toolkit (CTAEMOESGT)

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop a Cyber Terrain and Electromagnetic Operating Environment (EMOE) Scenario Generation Toolkit (CTAEMOESGT) software that can generate various real world scenarios/use cases/vignettes. This capability will enhance and aid in planning with the use of simulation Cyber Electromagnetic Activities (CEMA) Tactics Techniques Procedures (TTP) within Doctrine, Organization, Training, Material, Leadership and Education, Personnel, and Facilities (DOTMLPF) environment.

DESCRIPTION: Develop a predictive tool that is able to enhance Cyber understanding and increases situational awareness within various types of terrains and Electromagnetic Operating environments. The increased ability shall be flexible enough to acquire various types of data inputs that encompass geolocations, relationship of organizational groups, types of urban and rural infrastructures (such as building structures, roads, and traffic flow of people and vehicles), and electromagnetic spectrum usage. This tool will provide trends and support the tactical and strategic decision making process.

PHASE I: Research and draft a feasibility study in a technical report that includes an approach to develop prototype software with the following considerations: 1) samples of scenarios with tips, hints, checklists, examples; and the specific information needs and justifications within the context of the operational intentions by decision-makers; 2) pre-emptive display of template for creating scenarios based on the selection of the fidelity levels, mission types, and events/scales of operations; 3) accurate identification of persons of interest and their malicious activities via multi-source collection/processing; 4) the mechanisms/features for aiding analysts with automation of template and workflows of intelligence driven scenarios based on requirements of the intelligence needs and mission planning; 5) Common Operational Picture (COP) to exhibit realistic activities and modes of conducts under various urban operational environments within Concepts of Operations (CONOPs); and 6) assessment of the lessons learned via the standard schemas/tools and interface with the selected government models and database together with the user friendly Human Machine Interface (HMI). The events and activities in each scenario should be modeled in generic and extensible modules to support creation of specific details and building of libraries of event/activity portfolio by the users. The models should be realistic and diversified to support pattern and link association for trend analysis. The technical report shall include all findings and technical approaches to develop a software prototype to proceed to Phase II.

PHASE II: Research and develop a prototype software and a technical report that capture and allow operators to simulate realistic and diversified scenarios in an urban environment. The prototype shall be able to predict the capabilities, intentions, and potential actions of persons of interest based on lessons learned and support a Course of Action (COA). The software will generate CEMA information for analysis in a usable format to support automated reasoning and a rationale to the user in order to support a decision. The technical report needs to identify the development findings and outcomes, along with the strengths and limitations for each software model, database, algorithm, and technique that was explored and used. In addition there should be a plan to enhance and transition the capabilities of the technology to a U.S. Army Program of Record.

PHASE III DUAL USE APPLICATIONS: The software developed in this effort may be leveraged in a broad range of potentially high payoffs for military and civilian applications. The predictive analysis capability will assist the military with decision aids to support U.S. Army Program of Record regarding force protection, mission command, surveillance, maneuverability, and training. The commercial potential could be used in modeling building infrastructures, determining the placement of communication systems, transportation, and industrial security. Overall the modeling and simulation tool would be an asset for short- and long-term planning to recognize and deter threats.

REFERENCES:
1. https://publicintelligence.net/us-army-cema/

2. https://apps.dtic.mil/dtic/tr/fulltext/u2/a562410.pdf

3. https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp6_01.pdf

KEYWORDS: Cyber Terrain, Electromagnetic Operating Environment (EMOE), Cyber Electromagnetic Activities (CEMA)

A20-039 TITLE: Air Surveillance Radar Classification Improvement

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate an advanced target classification algorithm that will allow a ground-based Multi-Mission Radar to discriminate among UAS, manned aircraft, and clutter (i.e., birds, vehicles, ground clutter, etc.) by using signatures, target track characteristics, and other features.

DESCRIPTION: With the emerging threat of Unmanned Aerial Systems (UAS), the ARMY is enhancing its ground-based Counter Target Acquisition (CTA) Radars with the ability to detect and track UAS. These ground-based Multi Mission Radars (MMR) are able to detect and track airborne objects, such as rockets, artillery, mortars, UAS, manned aircraft, and clutter (i.e., birds, vehicles, etc.). The MMR radars are currently limited in their ability to accurately discriminate among UAS, manned aircraft, and clutter. Misclassifying targets can cause an incorrect responsive action by U.S. forces in critical situations. Significantly improving the classification accuracy of MMR radars is a high Army priority. The main purpose of this effort is to investigate, develop, and demonstrate a classification algorithm that uses target features to discriminate between UAS, manned aircraft, and clutter with high confidence.

PHASE I: Identify candidate algorithms that address the challenge described in the objective section of this document. Investigate current classifier functionality, develop more suitable parametric models, conduct studies on candidate algorithms (size, power consumption, speed, and complexity, relative to available computer processing resources), investigate high resolution waveforms and the frequency at which they should be scheduled to be effective, and perform laboratory testing on viability of candidate models and algorithms. At end of Phase I, prepare and present a study report to do the following: (1) identify algorithms that improve classification, (2) provide process and schedule for productization into the software baseline, and (3) demonstrate a plan for Phase II.

PHASE II: Develop and demonstrate improvements to classify UAS, manned aircraft, and clutter into target type and sub-type categories using previously collected Radar Data and during Live Test Events at Yuma Proving

Ground, AZ utilizing current ground based ARMY radar systems.

PHASE III DUAL USE APPLICATIONS: Productization of improvements into the software baseline: provide analysis, design updates, implementation support, and systems engineering testing for proposed algorithmic updates developed under Phase I and demonstrated in Phase II. Additionally, update the software and firmware to accommodate the final design and provide the following: software source code and executable files, system/subsystem specification updates, and performance specification document updates. Lastly, prepare lab tests, engineering test plans, and procedures to demonstrate the performance of the algorithms during a test event.

Effective deployment of this advanced classifier may serve to enhance the performance of current and future ARMY Air Surveillance and Multi-Mission radar systems such as the AN/TPQ-50 and AN/TPQ-53. Both Programs of Record are funded annually for modernization efforts, commonly referred to as Modernization Development Efforts (MDE), which provide a conduit for the integration of improved hardware and emerging software algorithms. This includes initial design and development efforts, laboratory design, productization into the software baseline, and field testing. The general classifier approach also has applicability in non-military radar systems. The same algorithm improvements planned for DoD Radar Systems can be utilized by FAA radar systems and commercial systems to help with bird strike avoidance and UAS detection around airports.

REFERENCES:
1. Bilik, Igal, Joseph Tabrikian, and Arnon Cohen. "GMM-based target classification for ground surveillance Doppler radar." IEEE Transactions on Aerospace and Electronic Systems 42.1 (2006): 267-278.

2. Duda, Richard O., Peter E. Hart, and David G. Stork. Pattern classification. John Wiley & Sons, 2012.

3. Christopher, M. Bishop. Pattern Recognition and Machine Learning. Springer-Verlag New York, 2016.

KEYWORDS: Multi-Mission Radar, Target Classification

A20-040 TITLE: Mitigation of GMTI Radar False Alarms Due to Wind-Blown Foliage with Machine Learning Techniques

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: The objective of this task is to develop a machine learning technique for Ground Moving Target Indicator (GMTI) radars that will mitigate false alarms caused by windblown foliage and other nonstationary clutter while maintaining the ability to detect slowly-moving ground targets. GMTI radars will typically adapt a Constant False Alarm Rate (CFAR) threshold and/or form a conventional clutter map system. This clutter map contains the Radar Cross Section (RCS), Doppler bandwidth of the clutter return, the extent of region in which the persistent false alarms occur, and the probability density functions of the clutter data. Radar operators will commonly desensitize particular areas of coverage due to these high false alarms. While this approach will minimize the false alarms caused by dynamic clutter, large portions of the radar coverage area can be desensitized. This desensitization can allow an area to be penetrated by hostile forces.

The objective of this topic is to determine whether machine learning techniques are able to differentiate between areas of dynamic clutter that are unoccupied from those that contain ground moving targets. This effort will compare the performance of the machine learning approach versus that of a CFAR / conventional clutter map system as a function of the clutter characteristics (e.g., RCS, Doppler bandwidth, and temporal variability), the target speed, heading, RCS, time required to make an initial detection, and the tracking accuracy.

DESCRIPTION: Airborne and ground-based MTI radars are designed to detect, locate, and track slowly moving targets such as walking dismounts. A critical issue for these radars is persistent false alarms caused by nonstationary clutter such as windblown foliage, moving water, and rotating objects. This effort will design a machine learning technique that will improve radar detection, location, and tracking performance by first using simulation, and then demonstrating the technique on collected radar MTI data. A thorough understanding of both machine learning techniques and the operation and performance of GMTI radar must be demonstrated to successfully perform this effort.

PHASE I: Demonstrate through simulation a viable and robust machine learning technique to mitigation of GMTI radar false alarms. The simulation is expected to use statistical clutter based on user-specified RCS and Doppler bandwidth. Targets are expected to be simulated as constant speed with a user-specified RCS. The developer will compare these simulations against a conventional clutter map approach.

PHASE II: Further develop the machine learning technique to process various dynamic clutter / ground moving target data. Data sets will be provided by the Government or obtained by the performer from any available sources including a customer-owned GMTI radar. The developer will compare these simulations against a conventional clutter map approach.

PHASE III DUAL USE APPLICATIONS: Work with Army and industry partners to incorporate the machine learning technique within an existing or developmental radar system. The offeror will demonstrate the capability and applicability of the machine learning technique for both government and commercial applications. The offeror will provide a comprehensive commercialization program plan to ensure transition of this technology from military to commercial applications such as perimeter security, border security, or other military or civilian application.

REFERENCES:
1. Skolnik, Merrill. Introduction to Radar Systems. McGraw-Hill Inc, New York, 1992, Pp. 392-395.

2. Conte, E. et al. "CFAR detection of distributed targets in non-Gaussian disturbance," IEEE Transactions on Aerospace and Electronic Systems, 38, 2 (2002).

3. Guo, Sai, et al. "Sea Clutter and Target Detection with Deep Neural Networks," 2nd International Conference on Artificial Intelligence and Engineering Applications, 2017

KEYWORDS: GMTI Radar, Clutter Suppression, Machine Learning

A20-041 TITLE: Low Probability of Intercept Sense Thru Wall Radar

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Build and demonstrate a Low False Alarm, Low Probability of Intercept (LPI), Thru Wall Radar System

DESCRIPTION: U.S. Army requires the tactical capability to quickly detect, locate, and discriminate hidden chambers and people. The automated sensor system must be able to distinguish between a normal space, for example the space between wall studs, and an occupied space to enable the operator to quickly focus their Sensitive Site Exploitation (SSE) operations. The system needs to operate with various common building materials, including brick, cinder block, concrete, wood, sheet rock, etc. The system needs to be automated, easy to operate, and not require specialized technical training to interpret. The urban Warfighter must be able to increase his/her situational awareness in an expeditious manner. This proposal will enable non-wall contact detection of hidden chambers and personnel. Critically important in sense thru the wall programs is achieval of a low false alarm rate due to complex clutter environments and multi-path. Thru Wall Radar System must be immune to interference (e.g., simple jammers). The radar signals must also be Low Probability of Intercept (LPI) and Low Probability of Detection (LPD).

PHASE I: Offeror will demonstrate their knowledge and understanding of state-of-the-art RF systems and their practical application. Offeror will highlight their understanding of operational parameters facing the dismounted and mounted Soldier, as it relates to thru wall detection, in the modern Army. The Offeror will design a radar system with LPI/LPD characteristics and low false alarm rate.

PHASE II: Design, develop, build, and test a mounted and dismounted RF prototype radar for thru wall applications.

PHASE III DUAL USE APPLICATIONS: Offeror will work with the Army and industry partners to create a commercialization and manufacturing plan for the system to support fielding by an Army program of record. The Offeror will illustrate a comprehensive commercialization program plan to ensure transition of the technology from military to commercial application.

REFERENCES:
1. Walton, “Ultrawide-band noise radar in the VHF/UHF band” - Jul 1999 · IEEE Transactions on Antennas and Propagation

2. Walton, “Random Noise Radar” – Live Science 2006

3. Skolnik, Merrill. Introduction to Radar Systems. McGraw-Hill Inc, New York, 1992

KEYWORDS: Low Probability of Detection, Low Probability of Intercept, Anti-Jam, RADAR

A20-042 TITLE: Federated/Encrypted Biometrics System (FEBS)

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Research and develop a federated identity management software system that leverages techniques to match encrypted biometrics (such as fingerprint, face, iris, Deoxyribonucleic Acid (DNA), etc.) data and utilize multiple techniques that encompass biometric template protection. The work will leverage a feature transformation and multi-biometric cryptosystems utilizing secure biometric schemes to create derived biometric templates. This approach will create revocability/renewability and un-linkable identification information that is not directly traced back to the original biometrics, thus increasing data security.

DESCRIPTION: The integrated biometric capabilities across the Joint, Interagency, International, Multinational (JIIM) communities greatly increase overall Identity Activity mission readiness in Biometric Enabled Intelligence (BEI) analysis, in support of theater operations with mission enablers for force protection, intelligence, physical and logical access control, identity management/credentialing, and interception operations. Therefore, there are urgent needs, such as maintaining confidence and strengthening our relationships with international communities by demonstrating a wider array of biometric protection capabilities to partner nations. The overall security of this development will minimize or prevent access to biometric data. In the enrollment stage, biometric data is stored as a reference template in a standard format. The biometric data of the person of interest is transformed (or rather derived) into a candidate biometric template for matching against the reference template and cross-matching templates from different databases. The derived biometric template is designed to reveal little or no information about the original biometrics of an individual. The derived biometric template from the original template should conform to the requirements of irreversibility, revocability/renewability, and un-link-ability. “Irreversibility” emphasizes that it is impossible to generate the original template from a person’s derived biometric template. “Revocability/Renewability” implies the ability of revoking and re-issuing the derived biometric template. “Un-link-ability” prohibits the trace of the multiple derived biometric templates to the same original template. The optimal solution is the federated biometric software system with novel techniques to identify/verify invaluable and irreplaceable identity information within an enterprise environment. To maximize protection, the proposed federated software systems should be able to run application software tools at various local storage of derived biometric templates that use encrypted protection schemes/mechanisms in the multi-biometric cryptosystems.

PHASE I: Research and list various types of technologies associated with the proposed approach to develop a prototype software and a technical report that has the following considerations: 1) leveraging existing technologies and upcoming technical advances that address the technical challenges; 2) provide a detailed description of the problem areas and the associated solutions with full explanation of the proposed disciplines, procedures, techniques, capabilities, and resources; 3) describe the operational constraints, feasibility of each approach, capability, applicability, assumption, and restrictions of the outcomes of the proposed effort; 4) indicate which software architecture and development environment (software tools, interface requirements, specifications of input/output data, etc.) would work optimally in a Windows (laptop and desktop) environment; and 5) list the methods and criteria for the performance measurements. Deliver a technical report on the study findings, algorithms, models, techniques, and software architecture of the proposed software system for the next phase development along with the implementation and evaluation plan of the proposed capabilities.

PHASE II: Research and develop a prototype software and technical report that captures the following focus areas: 1) encrypted-derived biometric templates; 2) multi-biometric cryptosystems; 3) processes of encrypted biometric data via application tools at the local storage level for identification and verification of people of interest; 4) enhancement of models of running multiple application tools at various local databases; and 5) development of scientifically sound methods (metrics, experiments, etc.) to evaluate the overall capability of the software. The technical report shall list the strengths and limitations of all algorithms, software models and techniques, and proposed architectures that were explored.

PHASE III DUAL USE APPLICATIONS: The techniques and algorithms developed in this effort may be leveraged in a broad range of potentially high payoff military and civilian applications. The prototype system will increase the protection of data and enhance the identification of people of interest. The focus is to transition the development into U.S. Army Programs of Record that support the commander’s decision and increase situational awareness. In addition to supporting not only military and other government agencies to identify, track, and reunite civilian populations during Security, Stability, Transition, and Reconstruction (SSTR) and Humanitarian and Disaster Relief (HADR) efforts. Law enforcement agencies and private companies will have the capability to enhance their security and protect Personally Identifiable Information (PII) data.

REFERENCES:
1. https://medium.com/syncedreview/federated-learning-the-future-of-distributed-machine-learning-eec95242d897

2. https://www.researchgate.net/publication/278671027_Identification_Using_Encrypted_Biometrics

3. https://pdfs.semanticscholar.org/83de/c5bff60692964a140180e71e6775ab54991e.pdf

KEYWORDS: Federated identity management, irreversibility, revocability/renewability, and un-link-ability

A20-043 TITLE: Innovative Approaches for Aided Target Recognition (AiTR) of Army Targets

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop approaches for AiTR that advance the state-of-the-art for specific military applications, sensors, and operating conditions.

DESCRIPTION: In recent years the research area of computer vision, a subfield of Artificial Intelligence (AI), has received significant attention and investments from both commercial and Department of Defense (DoD) sources. The principal trend has been to use deep learning-based approaches to automate both feature generation and object classification. While this approach has many advantages, especially in commercial applications, it has many disadvantages and limitations in DoD problem spaces. This is due largely to dynamic and unpredictable operating environments, uncooperative targets (e.g., partially concealed or in tree lines), and of course a shortage of data relevant to the problem space.

The Army desires innovative approaches for improving performance, robustness, and/or training efficiencies for Army AiTR systems. Possible improvements could be, but are not limited to the following:

- Improved probability of detection and false-alarm rates for AiTR algorithms against Army relevant targets with infrared (IR) imagery
- Approaches to train algorithms using reduced amounts of data (e.g., transfer learning, synthetic data)
- Manually created features that perform as good, or better, to deep learning automated features against Army relevant targets with IR imagery
- Algorithm improvements to increase robustness to unpredictable and untrained on environments and backgrounds
- Methods to quickly update a trained algorithm to a new target of interest without requiring the algorithm to retrain on previous target data

Solutions proposed to this topic should describe an innovative and novel approach to current state-of-the-art AiTR algorithms. The proposal should explicitly describe the innovative aspect of the proposed solution and specify how and why this innovation is helpful to the Army AiTR mission. Where possible provide quantitative metrics.

PHASE I: The proposer shall complete a proof-of-concept AiTR algorithm. This proof-of-concept shall demonstrate the proposed solution and the improvement it provides against the current state-of-the-art. For this phase the proposer shall use their own data. Government Subject Matter Experts (SMEs) will evaluate the proposer's design and results to determine utility against Army problem sets.

PHASE II: In Phase 2 the proposer will be provided IR data against targets and environments relevant to Army operations. During this phase the proposer will mature the AiTR approach to a TRL 6 level. In this phase the proposer shall evaluate improvements provided by this solution over current state-of-the-art commercial approaches. Army SMEs will evaluate the final solution against an Army sequestered dataset to determine improvements over current Army approaches.

PHASE III DUAL USE APPLICATIONS: Transition the developed approach to Army programs of record (PORs) and Army Futures Command (AFC) Cross Functional Teams (CFTs). In this phase the algorithms will be integrated into on-board processing hardware and platform software systems. Additional maturation of the algorithms using actual platform sensor data will take place.

REFERENCES:

1. Haykin, S., [Neural Networks and Learning Machines], Pearson Education, Inc., (2009)

2. James A. Ratches, "Review of current aided/automatic target acquisition technology for military target acquisition tasks," Opt. Eng. 50(7) 072001 (1 March 2011)

3. J. A. Ratches, C. P. Walters, R. G. Buser and B. D. Guenther, "Aided and automatic target recognition based upon sensory inputs from image forming systems," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 19, no. 9, pp. 1004-1019, Sept. 1997

KEYWORDS: ATR, AiTR, artificial intelligence, machine learning, computer vision, image processing

A20-044 TITLE: Novel Single Plane Optics for Lightweight, Compact Imaging Systems

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate an innovative optical element with broadband color correction with applicability in the MWIR (3-5 micrometer) or LWIR (8-12 micrometer) wavebands. The element should be capable of meeting high optical performance using flat surfaces on a thin (<1 mm) substrate with sub-wavelength or super-wavelength sized features formed on the surface.

DESCRIPTION: As the Army continues to develop focal plane array (FPA) technology, it moves in either the direction of smaller, lighter electronics or larger formats and therefore physical size. In the first instance, these FPAs can be utilized by the Warfighter as situational awareness devices in conjunction with lightweight personal drones. Their performance in this application can be limited by the optics required to form an image onto the FPA. Conventional optics exceed the SWAP payloads these extremely small devices are able to accommodate and the system’s full potential will remain unrealized. In the second case, FPA sizes grow and the optics required for them also grow proportionally. The larger FPAs with greater pixel counts can enhance the situational awareness, survivability, and lethality of the Warfighter. However, the larger optics required and the weight associated can put a strain on the Soldier and decrease their ability to accomplish their mission.

Innovative technologies have appeared that allow for novel optical elements that can be on flat substrates of less than a millimeter thickness. The elements, alone or paired with another flat planar optic or a conventional optical element, will allow for very lightweight optics that maintain a high level of optical performance. The technologies that allow for this are features on the scale of the wavelength of light (sub-wavelength or super-wavelength) that can be formed on the surface of the substrate using photolithography or similar techniques as well as increased computing power and sophisticated software to allow for the design and optimization of these features.

As the technology development organization for the Army’s FPA and IR camera programs, the U.S. Army CCDC C5ISR Center NVESD provides research, development, and engineering support to programs such as Integrated Visual Augmentation System (IVAS), Soldier Borne Sensors (SBS), and Enhanced Night Vision Goggle (ENVG). In this role, C5ISR Center NVESD is seeking to partner with a small business to develop optical elements that can focus broadband wavelengths with an element that has a thickness of less than 1 mm. Wavebands of particular interest to the Army are the SWIR (1-2 micrometers), MWIR (3-5 micrometers) and, particularly in the short term, LWIR (8-12 micrometers). To support uncooled operation, these lenses will require diffraction-limited or near diffraction-limited performance at low f-numbers (F/0.9 to F/1.2) with high efficiency (>80%) across the waveband.

PHASE I: Identify the key parameters and requirements associated with military optical systems. Conduct initial studies and design effort related to producing a planar lens on an appropriate substrate for MWIR or LWIR wavebands. Determine necessary equipment and manufacturing process to fabricate planar optical elements. Produce initial proof-of-concept lenses using the design and manufacturing processes to show viable path to meeting Army program requirements.

PHASE II: Produce planar optical elements on appropriate substrate. Demonstrate diffraction-limited or near diffraction-limited optical performance across a large waveband with high-efficiency at a low f-number. Demonstrate ability to maintain performance across a 30 to 50 degree horizontal field of view. Subject planar optical elements to necessary environmental tests, such as temperature, to show applicability to military systems. Demonstrate path to manufacturing planar optical elements at production quantities. Deliver prototype lenses to C5ISR Center NVESD for further testing and application.

PHASE III DUAL USE APPLICATIONS: Design and manufacture planar optics applicable to specific Army programs. Most likely applications for insertion include Soldier Borne Sensor (SBS), a handheld drone for squad level airborne recon and surveillance, Integrated Visual Augmentation System (IVAS), an augmented reality system for individual Soldiers, Enhanced Night Vision Goggles (ENVG), night vision goggles with LWIR camera imagery overlaid, or miniature cameras for covert persistent surveillance.
Dual-use applications for planar lenses include any application where thermal cameras are used. Potential applications include law enforcement, fire-fighting, hunting, and paranormal research.

REFERENCES:
1. N. Mohammad, M. Meem, B. Shen and R. Menon, “Broadband imaging with one planar diffractive lens,” arXiv:1712.09179 [physics.optics]

2. P. Wang, N. Mohammad and R. Menon, “Chromatic-aberration-corrected diffractive lenses for ultra-broadband focusing,” Nature Scientific Reports 6, 21545 (2016)

3. W. Chen, et al., (2018, March) “A broadband achromatic metalens for focusing and imaging in the visible,” Nature Nanotechnology, Vol. 13, pp. 220-226

KEYWORDS: Optics, Planar Optics, Metalenses, IR Lenses, Diffractive Optics

A20-045 TITLE: Additive Nanostructured Arrays (ANA) for Broadband Anti-Reflectivity (AR)

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and deliver optical elements that minimize reflection and improve light transmission by the additive fabrication of nanostructured arrays. The fabrication of ANA should include growth methods for IR lensing materials including Ge, ZnS, GaAs, and CaF_2.

DESCRIPTION: U.S. Army sensor systems are complex optical instrumentation with rigorous requirements related to their function and operational environments. These requirements lead to very complex optical designs, particularly for imaging systems in the inferred operating at broadbands such as 3-12 µm. For complex systems with many optical elements, it is imperative to reduce unwanted reflections and maximize transmission to the focal plane array. A promising method of reducing reflection is an array of subwavelength features on the surface of an optical element. These features effectively create a gradient refractive index reducing reflection leading to higher transmission. This method is inspired by nature and is often referred to as a "moth eye coating" and has many advantages over other means of AR coatings, including being broadband, omnidirectional, and polarization-insensitive.

The Army desires methods of creating additive nanostructured arrays on IR lensing materials. These methods should effectively grow crystals of the substrate lens material at a high aspect ratio perpendicular to the surface to create the desired anti-reflective effect. These methods can include but are not limited to colloidal growth and chemical vapor deposition. Proposed methods should limit lithography and etching methods.

A method is required for each of the IR lensing materials, Ge, ZnS, GaAs, and CaF2, with the resulting ANA reducing reflection to below 1% in the 3-12 µm band at incident angles of up to 60°. The method should be able to accommodate substrates from 12-155 mm in diameter and with a curvature of twice the radius. The high-rate production should not significantly increase the cost of optical elements and should be able to be applied to uncoated COTs lens. Successful ANA AR strategies will be supported and implemented through the appropriate Army Cross-Functional Teams and Program Offices. This topic would have particular benefit to the 3rd Gen FLIR Program of Record and its support to the Next Generation Combat Vehicle Cross Functional Team (NGCV CFT).

PHASE I: The proposer shall complete an exhaustive literature search and report to the Army experimental strategies for fabrication of ANA for each of the IR lensing materials. The report shall also include design parameters for the ANA that will make effective AR coatings. These conclusions should be supported by modeling efforts and peer-reviewed literature.

PHASE II: Using the results of Phase I, fabricate and deliver a flat and cured examples of all the IR lensing materials for Army evaluation. Each method of ANA manufacture should be well documented and the resulting features thoroughly characterized. Examples of each will be subject to the Army environmental and durability testing procedures.

PHASE III DUAL USE APPLICATIONS: Transition applicable techniques and processes to a production environment with the support of an industry partner if needed. Finalize a methodology production for elements with appropriate performance metrics. Determine the best integration path as a capability upgrade to existing or future systems. Commercially, this technology will be widely applied in devices in the telecommunications and aerospace industries.

REFERENCES:
1. Boehme, M.; Ensinger, W. "From Nanowheat to Nanograss: A Preparation Method to Achieve Free Standing Nanostructures Having a High Length/Diameter Aspect Ratio" Advanced Engineering Materials 2011. 13, 373. DOI 10.1002/adem.201000346

2. Qi, D. et al. "Bio-inspired Antireflective Heter-nanojunctions with Enhanced Photoactivity" Nanoscale 2013. 5, 12383. DOI: 10.1039/c3nr04011a

3. Cai, J. et al. "Self-cleaning, Broadband and Quasi-omnidirectional Antireflective Structures Based on Mesocrystalline Rutile TiO2 Nnanorod arrays" Energy Eniron. Sci. 2012. 107, 321. DOI: 10.1039/C2EE03573A

4. Ravipati, S. et al. "Broadband and wide angle antireflection of sub-20 nm GaAs nanograss" Energy Environ. Sci., 2012. 5, 760. DOI 10.1039/C2EE2155*F

KEYWORDS: Optics, Anti-Reflective Coating, Infrared Sensor

A20-046 TITLE: Self-Healing Optical Elements

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and deliver optical elements that will independently repair damage. The self-healing optics should be capable of returning to their originally manufactured performance after receiving either physical or laser damage. The repair mechanism should be initiated by the damage and require no human triggering and be completed within seconds.

DESCRIPTION: U.S. Army sensor systems consist of the most advanced technology available and are routinely subjected to extreme environments including heat, cold, sand/dust, high winds, and intense lasers which can result in their damage. It is a burden upon the Army in terms of materiel and labor to replace these elements but an even greater threat is the tactical disadvantage of a system becoming inoperable during maneuvers. The Army desires a method of creating self-healing optics that can be applied to its sensor systems. The self-healing mechanism can be implemented in either of two ways: as a coating that can be applied to existing optics or as the development of a new material suitable in high-performance optical elements including mirrors and lenses. Self-healing coatings or materials should be designed to be as broadband as possible, including as much of the 0.2-20 µm spectrum as possible. The self-healing capability should repair damage up to 0.5 mm deep from the elements surface within 2 seconds. Self-healing elements should be able to span sizes from 12-155 mm in diameter. The functional lifetime of an element should exceed 5 years or 10,000 damage repairs before a 2% degradation in performance.

The high rate production should not significantly increase the cost of optical elements and total cost of an element should be below $1 per mm2. Unrequired features of interest include compatibility with anti-reflective nanostructured array coatings, greater than 95% reflective mirrors in the 3-10µm band, and mirrors with tunable laser damage thresholds. Successful self-healing strategies will be supported and implement through the appropriate Army Cross-Functional Teams and Program Offices. This technology would be particularly useful for the NGCV and FVL CFTs due to the stressing environments that exposed optics encounter as these vehicles traverse dust, smoke, dirt, fog, soot, rain, etc.

PHASE I: The proposer shall complete a conceptual design of a self-healing system for effectiveness against physical and laser damage and demonstrate experimental proof of principle.

PHASE II: Using the results of Phase I, fabricate and deliver a fully functioning prototype meeting the performance metrics. The prototype should meet all the requirements for TRL 5: “basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment,” and be on the way to meeting TRL 6: “prototype system, which is well beyond that of TRL 5, is tested in a relevant environment.” At the end of Phase II, the selection and demonstrated implantation of this technology into an Army system is desired.

PHASE III DUAL USE APPLICATIONS: Transition applicable techniques and processes to a production environment with the support of an industry partner if needed. Finalize a methodology production for elements with appropriate performance metrics. Determine the best integration path as a capability upgrade to existing or future systems. Commercially, this technology will be widely applied in devices such as cell phone screens, eyeglasses, sporting optics, and automotive glass.

REFERENCES:

1. Smimov, E. et al. “Self-healing gold mirrors and filters at liquid–liquid interfaces” Nanoscale 2016. 8, 7723 DOI:10.1039/C6NR00371K

2. Edel, J. et al. “Self-Assembly of Nanoparticle Arrays for Use as Mirrors, Sensors, and Antennas” ACS Nano 2013. 7, 9526. DOI: 10.1021/nn405712r

3. Luo. X. et al. ‘Shape Memory Assisted Self-Healing Coating” ACS Macro Lett. 2013. 2, 152. DOI 10.1021/mz400017x

KEYWORDS: Self-Healing, Optics, Laser Damage

A20-047 TITLE: Energy Storage with an Embedded Battery Management and Inverter Subsystem

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: The objective of this effort is to investigate, develop, and fabricate a scalable, modular, highly energy dense, smart battery solution set comprised of an energy storage source (6T format) with an embedded battery manager and inverter subsystem. Successful execution of this effort will result in benchmark reliability and operational flexibility characteristics critical to Soldier, robotic enablers, and remote system (weapons and communications) applications in support of Soldier Lethality, Network, and Next Generation Combat Vehicle (NGCV) CFTs.

DESCRIPTION: To ensure successful outcomes in the tactical battlespace, all operations require the capability of, and reliability from, electrical power. Therefore, to enable and support the initial phases of offensive and defensive tasks, Soldiers typically use a hybrid power/energy configuration comprised of portable batteries, renewable power supplies, low-voltage generator sets, and the associated hardware to support electro-mechanical interfaces. While a viable approach, it is not always practical in terms of the operational compatibility of a given battery chemistry within varying tactical environments, of the functional interfaces between the battery and inverter, and of Soldier carry, mobility, and ease of use. Commonly available low-voltage COTS batteries may not be immediately suitable for use in certain tactical environments or applications. Energy inefficiency, parasitic power loss, and thermal management issues can arise if the power electronic inverters, battery management system, and selected battery chemistry are incompatible. Finally available COTS inverters are not designed to handle the impact of nonlinear loads and are many times too large and heavy for tactical applications.

To take advantage of a true hybrid power and energy solution, the Army seeks a Soldier portable (lift/carry) smart battery with an embedded battery manager and inverter subsystem for tactical applications in a multi-domain operating space. Solutions sought shall be modular and scalable to support operations requiring 2 to 5 kW. Final results shall enable a less complex system configuration with minimal to no interface hardware.

PHASE I: Develop conceptual component, subsystem, and system-level scalable (2 – 5 kW) / modular smart battery with embedded inverter and battery manager design in accordance with the following metrics.

Battery:
• COTS Li Ion – 6T format
• 24 V module w/programmable DC or AC output

Embedded Inverter:
• Scalable serial connection: 24 V increments
• Parallel connection: to enable multiple battery
• Variable DC voltage: 3.6 - 48 VDC,
• Fixed AC: 1-Phase: 120 VAC
• Fixed AC: 3-Phase – 120/208 VAC
• Variable AC frequency: 50 and 60 switch selectable

Battery Management: Cell-level voltage, cell temp, and SoC monitoring; module/string voltage and current; failure isolation

Communication Interface: ModBUS TCP/IP; CANbus with progression to TMS as it becomes available

Transport: Ability to be safely transported by commercial and military vehicles and aircraft

Results of Phase I shall support battery selection and its integration with the appropriate battery management system and inverter circuitry to realize a scalable, modular hybrid intelligent battery system design for execution in Phase II. Phase I discussions and design should include the following elements:

a. Narrative and graphical depiction of the design
b. Projected physical attributes
c. Projected performance metrics
d. Identification of the Technology Readiness Level of the technology

PHASE II: Design and develop a fully integrated proof-of-concept Energy Storage System with an Embedded Battery Management and Inverter Subsystem based on the Phase I results. Integrate and demonstrate operation and function with the Army 2 kW GenSet. Conduct operational/functional tests to confirm performance. Provide an interface design to support the subsequent scaling to outputs commensurate with integration/interface onto Soldier, robotic enablers, and remote weapon/communication platforms.

PHASE III DUAL USE APPLICATIONS: Finalize development of a modular Energy Storage System with an Embedded Battery Management and Inverter Subsystem. Identify target markets for the system and an industry partner for production of the system. Determine feasibility of teaming with a battery OEM (original equipment manufacturer) for development of an Advanced Technology Demonstrator. Develop partnerships with individual companies and Platform PMs (such as PM-E2S2 and PM-SWAR) for rapid fielding of results into the STEP procurement effort by FY25 and the Network and NGCV demonstrations for FY24.

REFERENCES:
39th Chief of Staff of the Army’s Modernization Priorities #1

2. Performance Specification, Batteries, rechargeable, Sealed General Specification, MIL-PRF-32383

3. Hitz, G. T., Mcowen, D. W., Zhang, L., Ma, Z., Fu, Z., Wen, Y., . . . Wachsman, E. D. (2019). High-rate lithium cycling in a scalable trilayer Li-garnet-electrolyte architecture. Materials Today, 22, 50-57. doi:10.1016/j.mattod.2018.04.004

4. MIL-STD-1332B - Definitions of Tactical, Prime, Precise, and Utility Terminology for Classification of the DoD Mobile Electric Power Engine Generator Set Family (DoD Power Quality Metrics)

5. MIL-HDBK-454 - Standard General Requirements for Electronic Equipment

KEYWORDS: Energy Storage, Embedded BMS and Inverter, Soldier Lethality, Next Generation Combat Vehicle – Robotic Enablers, Portable, Tactically Compatible.

A20-048 TITLE: Next Generation Hybrid Power Technologies for 2 – 5 kW Power Systems Supporting Soldier Applications in the Multi-Domain Battlespace

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: The objective of this effort is to develop and integrate a small, lightweight JP-8 fuel burning engine into a power generation system capable of providing a variable output of 2 to 5 kW of full continuous power at 4000’ 95oF. Successful execution of this effort will result in benchmark mobility (portability), reliability, and survivability characteristics critical to Soldier, unattended ground sensors (UGS), and remote system (weapons and communications) applications in support of the Soldier Lethality CFT. Successful results can also be leveraged to support power requirements for Network and Next Generation Combat Vehicle (NGCV) priorities.

DESCRIPTION: The Army has a great need for highly power dense (< 120 lbs), variable output JP-8 fuel burning power generation systems in the < 5 kW range to enable unmanned ground sensors and Soldier systems and operate remote weapons and communication systems. However, there are numerous difficult, technical challenges with the use of heavy fuel in conventional, small engines. Since the ‘90s, the Army has pursued various solution paths to realize a versatile power source that is man-portable and operationally and functionally compatible within the tactical environment. In the less than 9 hp range, gas turbines become extremely inefficient, and IC engines have difficulty burning JP-8. Small IC engines run at high speeds and have very short “strokes” in their power producing process, making efficient diesel combustion difficult. To address issues with fuel atomization and the injection/burning process, the Army invested in two approaches. Investments focused on the development of external combustion engine concepts (such as the Stirling cycle), but at the cost of increased mass and weight and reduced power density. The Army also invested in the adaptation and scaling down in size of reformers, high pressure pumps, and atomizing nozzles to realize fuel processors that enabled the combustion of JP-8 fuel within an existing small sized gasoline engine. This came at a cost of reduced operational environments and power quality, starting difficulties, severe engine derating, and unknown potential long-term maintenance issues.

This solicitation seeks
1) innovative concepts to efficiently atomize/vaporize unmodified (no additives) JP-8 fuel, per the Army’s One Fuel Forward Policy
2) engine configurations that allow for longer burn times
3) external burning concepts combined with cycles other than the Stirling cycle
Note: Spark ignition and gas turbine engines are also explicitly excluded from this solicitation. The proposed variable speed engine must be fuel-efficient, power-dense, and able to readily burn unmodified heavy fuel (JP-8).

PHASE I: This effort will include the use of a model/simulation tool to evaluate alternative electromechanical and hybrid prime mover technologies to include emerging novel rotary diesels, fuel cells, etc. which can be integrated into a system configuration to generate a variable output of 2 to 5 kW of tactical electric power for Soldier, UGS, and remote applications. The function and operation of a given prime mover will be evaluated to determine its mechanical and electrical response under various loading conditions, control inputs, and environments. The effort will yield a proof-of-concept variable output power system based on emerging engine technology selected for its operational / functional suitability within a tactical environment. Develop conceptual component, subsystem, and system-level design in accordance with the following metrics:

- Fuel: JP-8,
- Output: 2 – 5 kW continuous output up to 4000’, 95 F
- Signature: < 70 dBA at 7 m; < 60 dBA at 0.9m
- Environment: full-spectrum military environment (AR70-38 temperature extremes, MIL-STD-810 shock & vibration, sand & dust, humidity, blowing rain)
- Transport: Ability to be safely transported by commercial and military vehicles and aircraft

Results of Phase I shall support engine selection and its integration with optimal combinations power systems components / subsystems to realize a variable output (2-5 kW) power system design for execution in Phase II. Phase I discussions and design should include the following elements:
a. Narrative and graphical depiction of the design
b. Projected physical attributes (power density, energy density)
c. Projected performance metrics (fuel consumption, power output, etc.)
d. Identification of the Technology Readiness Level of the technology

PHASE II: Design, develop, and demonstrate a proof-of-concept variable output (2 – 5 kW) power source based on the Phase I results and provide an interface design to support the subsequent integration/interface with Soldier, UGS, and remote weapon/communication platforms.

PHASE III DUAL USE APPLICATIONS: Finalize development of a variable output 2 – 5 kW power system. Identify target markets for the system and an industry partner for production of the system. Determine feasibility of teaming with a generator set OEM (original equipment manufacturer) for development of an Advanced Technology Demonstrator. Develop partnerships with individual companies and Platform PMs (such as PM-E2S2 and PM-SWAR) for rapid fielding of results into the Small Tactical Electric Power Program (STEP) by FY25.

REFERENCES:
1. US EPA, 2003, Proposed Tier 4 Emissions Standards, EPA Document Number EPA420-F-03-008, http://www.epa.gov/nonroad/f03008.htm#q2

2. Front End Analysis of Mobile Electric Power Research and Development for 2015 - 2025 (July 2002);http://www.ee.uidaho.edu/ee/power/hhess/FrontEndAnalysis.pdf

3. Small Tactical Electric Power Specification (Draft - 28 June 2019). https://arpa-e.energy.gov/sites/default/files/Matthew_CERDEC_GENSETS_FINAL.pdf

KEYWORDS: Variable output generator set, man-portable power, soldier lethality, remote weapons/communication system power, UGS power, integrated tactical network

A20-049 TITLE: Small Arms Bullet Tracking Techniques and Algorithm Developments for Improved Soldier Lethality

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate ability to track small arms ammunition projectiles in real time from the platform point of origin to point of impact, using passive or active imaging techniques with any associated algorithms and/or image processing, with an objective to improve Soldier Lethality and eliminate or reduce the need for tracer rounds.

DESCRIPTION: Using weapon-mounted, or close proximity, video from standard or specialty imagers in a variety of wavebands, determine the best method for tracking small arms ammunition projectiles from the weapon point of origin, in flight, to their impact point. Approaches may use passive or actively illuminated techniques, and may include bullet modifications, for both day and night applications with potential to correct or adjust reticule aim point. All techniques will be subject to size, weight, power, and cost concerns associated with Army fielding and Dismounted Soldier requirements.

PHASE I: Phase I investigates advantages and disadvantages of approaches and techniques to imaging and/or tracking small arms projectiles in flight, from origin point at weapon to include impact point, with specific imager selections and imaging modalities. Approaches may include passive or active illumination, with image processing, for both day and night applications. While techniques using existing ammunition are desired, approaches may also include modifications to the projectile itself, but the modifications must be compatible with the cost and manufacturing of small arms ammunition. Radiometric/photometric analysis, with signal to noise ratios, should be included to indicate compatibility of bullet tracking capability with selected Electro Optic imagers and various backgrounds in support of recommended solution space.

PHASE II: Phase II develops and integrates a brass board prototype system for data collections and determination of viability for selected techniques.

PHASE III DUAL USE APPLICATIONS: Phase III determines potential applicability to law enforcement and Department of Homeland Security (DHS), while developing and integrating a prototype system for demonstration. Size, Weight, Power, and Cost will be the focus of final system design, with further emphasis on ease of user operation.

REFERENCES:
1. Austin A. Richards and David M. Risdall "Passive thermal imaging of bullets in flight", Proc. SPIE, vol. 5405, p. 258-263 (2004).

2. Roberts, Randy S, and Breitfeller, Eric F. System and method for bullet tracking and shooter localization. United States: N. p., 2011.Web.

3. Murray, Kevin H., BULLET DETECTION AND TRAJECTORY ESTIMATION, Thesis paper, George Mason University, 2017.
http://mars.gmu.edu/jspui/bitstream/handle/1920/10944/Murray_thesis_2017.pdf?sequence=1&isAllowed=y

KEYWORDS: small arms, bullet tracking, tracer, active imaging, image processing

A20-050 TITLE: Dual-Band Lens SWAP Reduction and Increased Optical Throughput with Calcium Lanthanum Sulphide (CLS)

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design and fabricate a dual-band relay imager lens assembly which leverages newly discovered infrared material, Calcium Lanthanum Sulphide (CLS), and/or a curved focal plane array (FPA). The relay imager lens assembly should demonstrate the impact of CLS or a curved FPA on overall size, weight, number of elements, and performance.

DESCRIPTION: The Army is acquiring dual-band FLIR thermal imaging systems for use on airborne platforms and ground-based platforms wherein the optics image both the MWIR and LWIR infrared spectrums. This includes the 3rd Gen FLIR Program of Record that supports the Next Generation Combat Vehicle (NGCV) Cross Functional Team (CFT). There are a limited number of materials which transmit both the MWIR and LWIR. Dual-band optical elements must correct aberrations to ensure all desired rays entering the optical assembly image correctly onto the focal plane. Of those aberrations, chromatic aberration contributes the most to the optical blur observed on the FPA. Chromatic aberration is a wavelength-dependent aberration where each wavelength focuses to a different location. Lens materials with complementary chromatic dispersions, i.e., change in index of refraction versus wavelength, are needed to correct for chromatic aberration in dual-band systems.

While existing optics demonstrate the capability of achieving high performance in dual-band sensors, the number of optical surfaces needed to establish such performance is also high because the available materials do not possess the ideal dispersion relationships. The number of elements in an optical system impacts the transmission of the assembly. Each optical element will attenuate the energy impinging on the focal plane, thus limiting the system range performance. In addition, these elements contribute to the assemblies' overall weight, size, and cost.

Recently NVESD has discovered that the optical properties of Calcium Lanthanum Sulphide (CLS) may be well-suited for use in dual-band sensors. Introducing CLS or a curved focal plane into the imaging system may reduce the number of elements required to meet diffraction-limited optical performance. Because of the limited number of materials which transmit in the MWIR and LWIR, the new CLS material properties may directly reduce the chromatic aberration in the optical system. Furthermore, a curved focal plane could aid in aberration correction by defining a field dependent focus location. Research of optical designs that take advantage of the new material and curved focal plane architectures is required to identify optimal forms which meet sensor needs. The following table of first-order parameters represents a typical system level requirement:

Focal length	94.4mm
Entrance pupil location (ref L1)	35mm
Entrance pupil diameter	39.1mm
Waveband	3.5-5um & 7.6-10um
Total length	94.5mm
Cold stop diameter	10.4mm
Cold stop height	25.15mm
Image plane diagonal format	17.62mm
Distortion (f tan(theta))	<3%

Table 1.1 First Order Optical Parameters

PHASE I: Perform trade studies and develop optical designs using CLS material and curved focal planes for re-imaging optics per Table 1.1. Trade analysis shall address issues of reducing lens count, ease of fabrication, athermalization, total optical transmission, and minimization of “Narcissus” back-reflections assuming a cryogenic dewar around the cold stop. Size, weight, and cost shall also be criteria for evaluating best possible design options. The design forms shall assume simple aluminum housings, and passive athermalization techniques using materials with differing coefficients of thermal expansion may be considered. Optical elements near the intermediate image plane shall avoid beam footprint diameters less than 1 mm. Designs shall have diffraction-limited performance across most of the image plane footprint. The results of these efforts shall be documented in a deliverable electronic format final report.

PHASE II: Using the results of Phase I, choose the best design approach for proceeding to fabrication and test of a “proof of design” demonstrator hardware optical system. Execute prototype fabrication and deliver the assembly to the government. A test plan shall be developed and executed in this phase to confirm performance and assess compliance with designed performance parameters. In addition, the offeror shall determine a path for hardware fabrication to include identifying material vendors, coating shops, and component integrators. The Government does not intend to provide a focal plane dewar assembly; therefore, commercially available prodcts may be considered for test & demonstration purposes. Deliver a final report containing final as-built design and test information.

PHASE III DUAL USE APPLICATIONS: Transition applicable techniques, processes, and material sources of supply to a production environment with the support of an industry partner if needed. Finalize a sensor design with appropriate SWAP-C and form factor based on human factors and operational testing. Determine the best integration path as a capability upgrade to existing or future systems, including firmware and interfaces required to meet sensor interoperability protocols for integration into candidate systems as identified by the Army. This topic supports NGCV (e.g., OMFV, RCV) through the 3rd Gen FLIR POR and FVL (e.g., FARA, and any combined pilotage + ASE missions such as DDUS).

REFERENCES:

1. Gentilman, R. L. (1988). Calcium Lanthanum Sulfide as a Long Wavelength IR Material. SPIE, 929, 57th ser., 57-64

2. Hills, M. E. (1990). Preparation, Properties, and Development of Calcium Lanthanum Sulfide as an 8- to 12-micrometer Transmitting Ceramic. Defense Technical Information Center

3. McCloy, J. S. (2013). Infrared-Transmitting Glass-Ceramics: A Review. SPIE, 8708, 1-20

KEYWORDS: Sensors, Optics, Imaging, Lens, Thermal

A20-051 TITLE: Algorithm-Based People Detection and Threat Determination from Passive Infrared and Visible Cameras

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: The U.S. Army requests algorithms to automatically detect people that pose a threat to Warfighters or civilians from real-time images acquired by passive cameras operating in mid-wave, long-wave and visible bands. Indictors of a threat situation are complex and may include scenarios where a person carries a visually identifiable weapon or a military equipment or a person abandons a bag in a crowded space. The proposed algorithm shall detect, recognize, and identify threat-level of personnel from sensor images.

DESCRIPTION: In combat, a Soldier needs to visually scan the battlefield quickly and detect, recognize, and identify threats. The accuracy and the speed of detection, recognition, and identification are of critical importance to the Soldier's ability to make tactical decisions. Computer vision algorithms can perform threat detection from visual data with speed unmatched by a human, and can therefore greatly aid the Warfighter on the battlefield by cueing the Soldier. In a military setting, optical or infrared cameras can be worn on a Soldier or mounted on a vehicle to provide real-time data. In the civilian world, there exists an urgent need to detect persons with an intent to harm from surveillance videos to protect public safety. During recent mass shooting events such as Marjory Stoneman Douglas High School in Parkland, FL in Feb. 2018 and the Tree of Life Synagogue in Pittsburg, PA in Oct. 2018, the shooter in each event carried at least one visually identifiable weapon as he left his vehicle and walked to the building where the shooting took place. Algorithms designed to detect and recognize a person who carries a weapon from live surveillance video could mean earlier notification of the threat situation to the authorities and potentially stopping the person before the crime can be carried out.
Detection refers to an algorithm's ability to distinguish the object of interest from background elements of the scene. The object may occupy few pixels when it is located at large distances. At this distance there may not be enough information to confirm what the object is. Recognition refers the algorithm's ability to determine the object's class. In this case class refers to person or non-person labels. Identification refers to an algorithm's ability to differentiate between objects within a class, for example, identifying whether the person is a Soldier or a civilian, is the person armed or unarmed, and is the armed person carrying a large or small weapon. In addition, algorithms provide contextual information about a person: is the person with a group, is the person waiting idly, walking, or running and at which speed and orientation. All of these elements inform a Soldier of the threat level of the detected object. Algorithms developed for personnel detection and threat determination should address the complexity of the scenes in real-life scenarios. Threat targets may be occluded partially or fully from the sensor's field of view by clutter sources such as trees, buildings, bright light, or moving crowds intermittently in time. Target visibility may also vary based on environmental factors such as lighting and time of the day. Training and testing data shall be collected to mimic scenes in which a person acts dangerously according to threat definitions. The algorithms shall provide

accurate detection and low false positives on targets who fit these threat definitions.

PHASE I: The performer shall conduct a trade study of existing algorithms for personnel detection and threat determination using passive sensors. They shall collect preliminary data in at least two threat scenarios, urban and natural. This data shall be used to demonstrate algorithms and show a capability to identify threats (i.e., armed individuals) from non-threats.

PHASE II: The performer shall further develop algorithms that detect, recognize, and identify personnel that pose a threat. These algorithms shall be applied to additional scenario data collected by the performer and Government. The new scenarios shall have greater complexity, occlusions, and clutter. These scenarios should include realistic urban scenes that include urban objects and street level activities typical of this environment, e.g., unarmed civilians and commercial vehicles. The rural environments will assume a larger field of view with fewer pixels on target; implicit in this environment is vegetation ranging in scale from grass and shrubs up through forests. In both scenarios, the scenes shall include static and dynamic clutter that represent bystander human and non-human activity. The performer shall quantify detection results in terms of detection probability and false positive probability and confusion matrices.

PHASE III DUAL USE APPLICATIONS: Further develop demonstrator algorithms to meet detection performance target set by the Army. Demonstrate real-time feasibility of demonstrator algorithms. Field the demonstrator algorithms on a system of cameras. Implement the algorithm on field hardware in scenarios similar to those previously described.

REFERENCES:
1. Mahajan, R., & Padha, D. (2019, May). Detection Of Concealed Weapons Using Image Processing Techniques: A Review. In 2018 First International Conference on Secure Cyber Computing and Communication (ICSCCC) (pp. 375-378). IEEE

2. Chen, H. M., Lee, S., Rao, R. M., Slamani, M. A., & Varshney, P. K. (2005). Imaging for concealed weapon detection: a tutorial overview of development in imaging sensors and processing. IEEE signal processing Magazine, 22(2), 52-61

3. Bird, N., Atev, S., Caramelli, N., Martin, R., Masoud, O., & Papanikolopoulos, N. (2006, May). Real time, online detection of abandoned objects in public areas. In Proceedings 2006 IEEE International Conference on Robotics and Automation, 2006. ICRA 2006. (pp. 3775-3780). IEEE

4. Grega, M., Matiolański, A., Guzik, P., & Leszczuk, M. (2016). Automated detection of firearms and knives in a CCTV image. Sensors, 16(1), 47.

5. Range Performance DRI Ratings Explained, INFINITY White paper, https://www.infinitioptics.com/sites/default/files/attachments/Infiniti%20Thermal%20DRI%20Whitepaper_0.pdf

KEYWORDS: Target Detection and Recognition, Image Processing, Public Security, Machine Learning, Deep Learning, Sensor Fusion, Information Processing

A20-052 TITLE: Moving Target Designation

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions.

Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and deliver prototype hardware capable of beam steering a laser designator on moving targets during typical handheld operations when coupled to a sighting optic.

DESCRIPTION: Ground designation events are typically static scenarios (non-moving targets; designators on stable platforms). This type of scenario increases carry weight (stable tripod) and restricts Concepts of Operations (ConOps). However, munition platforms are capable of flight corrections during designation events for a period of time up to terminal guidance. In order to capitalize on the munitions capability, technology must be developed to not only stabilize the beam but lock and track moving targets as well. The Army desires a device that can be paired with an appropriate see-spot (images the laser energy) camera, track and designate a target (4.6 m^2) moving >35 kpm at 3 km (Threshold) or >45 kpm at 5 km (Objective) for >30 seconds under typical User hand motion. The overall designator portion of the development, to include batteries, shall be <3.25 lbs, <100 in^3, and <15 W Steady State, >30 mJ output energy (3 km range) or >50 mJ output energy (5 km range). The device must also produce visual indicators to the operator pertaining to the limits of beam steering travel. Full rate production costs should be <$30k. In addition, the system shall utilize the statistical Effective Designator Range equation (EDR95) in order to deduce the appropriate beam divergence and designator jitter appropriate for the application. This equation can be provided once under contract if necessary.

This device would support primarily the Long Range Precision Fires CFT by providing increased standoff distance to aircraft/munition platforms by providing Laser Guided Bombs (LGBs) greater "fire and forget" capability against mobile threats. The expanded ability for guiding LGBs from the ground provide improved Multi-Domain Operations, with a tactical, layered approach possible when encountering a more mobile adversary. In addition, this effort directly supports the Lethality CFT as well by increasing Lethality (expanded Tactics, Techniques, and Procedures [TTPs] across air and sea assets), Mobility (less required equipment; less weight), and Protection (expanded direct overwatch).

PHASE I: The proposer shall provide a complete prototype design. An approximate bill of materials should be provided as part of the design, including necessary components, power, and cost; this bill of materials shall be refined in Phase II.

A complete and thorough understanding of the algorithms necessary, if any, to make the sensor successful shall be demonstrated. Rigorous modeling and data collection shall be performed to estimate system performance to include handheld motion, minimum SWaP (size, weight, and power) beam steering mechanisms, appropriate camera pairing for resolution and frame rates, etc.

PHASE II: Using the results of Phase I, fabricate and deliver a fully integrated prototype meeting SWaP and performance goals. Prototype should meet all requirements for TRL 5: "basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment," and be on the way to meeting TRL 6: "prototype system, which is well beyond that of TRL 5, is tested in a relevant environment."

PHASE III DUAL USE APPLICATIONS: Transition applicable techniques and processes to a production environment with the support of an industry partner if needed. Finalize a sensor design with appropriate SWAP-C and form factor based on human factors testing. Determine the best integration path as a capability upgrade to existing or future systems, including firmware and interfaces required to meet sensor interoperability protocols for integration into candidate systems as identified by the Army. Commercially, this could be used as part of a laser deterrent system for border patrol or police force when used with different laser wavelengths.

REFERENCES:
1. Joint Chiefs of Staff, April 2019, Joint Fire Support -
https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_09.pdf

2. Neal Bambha and Dan Beekman, Dec 2017, US Army Research Laboratory -
https://www.arl.army.mil/arlreports/2017/ARL-TR-8243.pdf>

3. Naval Surface Warfare Center, May 2011, Naval Sea Systems Command - https://www.navsea.navy.mil/Portals/103/Documents/NSWC_Dahlgren/Laser/mil-h

KEYWORDS: Laser Designation, Forward Observer, Terminal Guidance, Missile Seeker

A20-053 TITLE: Cooperative and Coordinated Decentralized Warfare in Disconnected, Intermittent, Limited bandwidth (DIL) Environments

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Investigate and demonstrate an algorithmic approach to achieve cooperation and coordinated activity by a decentralized group of electronic warfare (EW) actors within a disconnected, intermittent, limited bandwidth (DIL) environment.

DESCRIPTION: Future operations within highly contested environments will drive the need for networks of systems able to rapidly adapt and respond to changing conditions, such as distributed EW systems for platform survivability. The intent is to field the EW systems onto Air Launched Effects (ALE) aerial vehicles, to enhance the capability of future aviation platforms to achieve dis-integrating effects through operating as a team with other manned and unmanned platforms to penetrate into the Deep Maneuver Area. The desired EW payload capabilities of the ALE include decoy and disruptive radio frequency electronic attack as well as passive and active threat detect, identify, locate, and report (DILR) electronic support. In order to accomplish these diverse missions within the Anti-Access and Area Denial (A2AD) environment, it is expected that these capabilities may reside on multiple different payloads. Novel methods of decentralized control of the EW payload behavior sets will be required for operation within the DIL environment enabling the individual EW system actors to infer the behavior of the other actors within the network.

Example missions include, but are not limited to, unmanned aircraft stand-in/stand-off jamming for aided survivability of manned aircraft, unmanned aircraft penetration and suppression of IADS to enable lethal effects and manned aircraft stand-in/self protect jamming.

PHASE I: Define a set of notional operational scenarios for implementing the EW behavior sets of the representative actors. Determine the global optimum for each scenario through optimizing the behavior of the actors for each scenario in a preplanned manner within a permissive communications environment.

PHASE II: Develop a set of algorithms to optimize the behavior of the EW actors in dynamic scenarios within a DIL environment. The algorithm needs to enable adaptation of actor behavior to changes in the optimization objective, resources and/or constraints of the EW actors, and the number and/or distribution of actors. Evaluate the performance of the algorithm across a variety of scenario permutations within a DIL environment.

PHASE III DUAL USE APPLICATIONS: Algorithms developed and tested during Phase II can be directly applied to future technology demonstrators to enable resilient operation of decentralized EW actors within dynamically changing operational scenarios under DIL conditions.

REFERENCES:
1. TRADOC Pamphlet 525-3-1

2. www.ted.com/talks/kevin_slavin_how_algorithms_shape_our_world.html

3. http://www.cs.cmu.edu/~sandholm/cs15-892F13/algorithmic-game-theory.pdf

KEYWORDS: Fratricide mitigation, resiliency, autonomous agents, artificial intelligence

A20-054 TITLE: High Fidelity IR Clutter Generator for Missile Warning Sensors

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: High fidelity background clutter generator is proposed for scene projection in Hardware-in-the-Loop (HITL) test and evaluation of Missile Warning Sensors (MWS).

DESCRIPTION: Performance testing of MWS sensors is hardware challenging due to the false alarm and realistic clutter environment background requirements. An MWS must be able to distinguish a threat against a clutter background and give a false alarm rate not greater than specified. A method of constructing high fidelity background clutter generator is proposed for scene projection in Hardware-in-the-Loop (HITL) test and evaluation of Missile Warning Sensors (MWS). Hardware performance testing, beyond benchtop component level, is designed to prompt and evaluate a desired response from the sensor to external stimuli (not injected scenes). To date, hardware test for 2 color MWS includes various models of 2 color scene projectors based on DMD technology with incremental improvements. The DMDs work well to achieve proper scene radiances and ratios and can be configured to provide high contrast by linear combination of modulator arrays and sources. Tests can be combined further to operate holistically with pointer/jammer HITL testing for combined system evaluation.

PHASE I: Study feasibility of novel high fidelity background clutter generation approaches, tuned specifically toward dual color IR clutter generator including all the IR wavelength regimes (SWIR, MWIR, and LWIR). Materials, efficiency, manufacturability, stability, and ruggedness on a flight motion table are all considerations. Specific designs and test results for mature implementation of new clutter generator will result.

PHASE II: As informed by Phase I, build a prototype dual color IR clutter generator. These prototypes would include any software items needed to test and develop IR models and scenes using this technology, which can then be used to stimulate IR sensors and countermeasure systems.

PHASE III DUAL USE APPLICATIONS: These projectors, once productionized, can support multiple Government test labs throughout DoD as well as Programs of Record.

REFERENCES:
1. Igor Anisimov and Yakov Soskind, "Infrared Dynamic Scene Projector"

2. Greg Franks, Joe Laveigne, Tom Danielson, Steve McHugh, John Lannon, Scott Goodwin, "Development of an Ultra-High Temperature Infrared Scene Projector at Santa Barbara Infrared Inc", proc. SPIE 9452, 94520W (2015).

3. Rodney McGee, Fouad Kiamiley, Nicholas Waite, Joshua Marks, Kassem Namha, Garrett Ejcak, Jon Dickason, Jake Benedict, Miguel Hernandez, "512x512, 100Hz Mid-wave Infrared LED Scene Projector", GOMAC Tech Conference, P-50 (2015).

4. Thomas M. Cantley, Gary Ballard, and Don A. Gregory, "Application of Type II W-Quantum-Well Diode Lasers for High-Dynamic-Temperature-Range Infrared Scene Projection", Optical Engineering 47(8), 086401 (2008).

KEYWORDS: infrared imaging, infrared imaging scene projector, threat detection, sensors, hardware in the loop, testing and evaluation

A20-055 TITLE: Prioritized Tactical Data Exchanges

TECHNOLOGY AREA(S): Battlespace

OBJECTIVE: The objective of this topic is to develop mechanisms that dynamically determine the value of data and information to soldiers involved in tactical engagements in a distributed, disadvantaged network environment.

DESCRIPTION: The Army has emphasized and will continue to emphasize smaller and more mobile command posts, with the goals of decreased logistics and manpower support, sustainable operational tempo, outperforming the enemy's command, and survivability of equipment and personnel. Those tactical conditions will also be characterized not only by limited computing resources, but by limited and/or sporadic bandwidth and well. As these themes are addressed, it will be challenging to supply effective Mission Command computing capability without a mechanism to dynamically determine the importance of data and information. As network and computing resources diminish, and the battlespace changes, it is imperative to prioritize information needs, in order to support decision making cycles.
Initial equipment and software allocation, battlespace sensing, threat analysis, systems and network availability, running estimates, forecasting, determination of related effects, current levels of situation awareness and understanding, redundancy and resilience across the formation, and capabilities and training of individual soldiers are examples of factors that might be considered in maintaining this assessment. Intelligent strategies for data and information creation, storage, routing, and mediation should be explored. This work would be a foundational piece of the data storage and transport strategies required to support dispersed Mission Command computing.

PHASE I: The goals of phase I are to identify the factors relevant to the dynamic prioritization of battlespace data and information, and to present those prioritizations across several use cases. The Brigade and Battalion echelons should be the initial focus of this study. All relevant and potential factors in determining data and information importance of as a military operation unfolds should be assessed. Mission Command systems, voice communications, face-to-face interaction, and the cognitive processes involved in maintaining operational tempo comprise an initial set of data and information categories for consideration. An initial scheme for adjusting priority levels as an operation unfolds, considering the factors listed in paragraph two of the Description above, is also desired.

PHASE II: Phase II work should begin with a maturation of the assessments performed during phase I. Updates to the factors considered, as well as the use case prioritization, are expected. Significant work on developing more sophisticated for adjusting priorities will be required. A concept demonstrator of the dynamic prioritization of a set of the data and information identified during Phase I is desired during a representative operation is desired. Initial designs of schemes for data/information retrieval, creation, storage, caching, and forwarding are also expected. The software developed should reach a Technology Readiness Level (TRL) of 6. The performer will work with the government to identify and participate in one or more technology demonstrations to Army stakeholders.

PHASE III DUAL USE APPLICATIONS: During Phase III, the software will be matured to a TRL 7. A series of demonstrations, simulations, or experiments intended to show responsiveness to priorities assigned to data and information from Mission Command systems, voice communications, face-to-face interaction, and cognitive processes is expected. The availability and bandwidth of network and communications, as well as the availability of Mission Command software systems and soldiers at physically separate locations, are factors that must be included. A robust data management / storage / routing solution is also required.

REFERENCES:
1. Army Doctrinal Reference Publication (ADRP) 6-0, Mission Command

2. Army Field Manual (FM) 6-0 COMMANDER AND STAFF ORGANIZATION AND OPERATIONS

3. Army Techniques Publication (ATP) 3-21.21 (FM 3-21.21) SBCT Infantry Battalion

4. https://www.c4isrnet.com/c2-comms/2018/01/19/the-army-wants-to-ensure-its-command-posts-arent-an-easy-target/

5. Government Accountability Office (GAO) ARMY MODERNIZATION Steps Needed to Ensure Army Futures Command Fully Applies Leading Practices

KEYWORDS: Value of Information, Data Strategies, Data Mediation, Command Post Integrated Infrastructure

A20-056 TITLE: Packaging Metal-Coated Fibers for Prolonged Storage and Efficient Dissemination

TECHNOLOGY AREA(S): Materials/Processes

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop a low-cost manufacturing process to pack metal-coated fibers to high density and which will allow efficient dissemination. Fibers are theoretically the highest performing particle shape for obscuration, especially in the microwave region of the electromagnetic spectrum. They can also be the most difficult to efficiently pack and to aerosolize. The process to pack fiber will probably, but not necessarily, use an aligned format. Efficient dissemination implies a maximum of single fibers and a minimum of clumps. Phase I will focus on strategies to address issue of less than optimum packing density and dissemination quality, e.g. galvanic corrosion and/or filament to filament adhesion that reduces performance for nickel-coated fibers. Phase II will expand the effort by addressing cold welding in copper-coated fibers. It will also include the ability to demonstrate the usefulness of the concepts by using accelerated storage techniques and performing dissemination trials to show improvements

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 and coating thickness. Numerical modeling and many measured results on metal-coated fibers affirm that more than order of magnitude increases over current performance levels are possible if high aspect-ratio conductive fibers can be effectively disseminated as an un-agglomerated aerosol cloud.

Since this is a relatively new area of research for the Army, very little work has been performed so far in this area. One of the difficult issues is the corrosion that results from galvanic reactions in the packing process that degrades the fibers. Another is the particle-to-particle attractive forces that make efficient dissemination of single fibers difficult.

PHASE I: Describe techniques to minimize mechanisms of filament to filament adhesion, e.g. galvanic corrosion, cold welding, or other means of metallic coating degradation, of nickel-coated fibers during packaging and prolonged storage. Demonstrate with samples an ability to produce packed metal-coated fibers with a bulk density of at least 50% of maximum theoretical bulk density of the nickel-coated fibers, with no degradation, and preferably improvements, in dissemination efficiency. Nickel-coated fibers are available commercially for this effort and should be cut to a length of one centimeter. (5) 100-gm samples shall be provided to ECBC for evaluation

PHASE I Option: Describe techniques to minimize cold welding in copper-coated fibers.

PHASE II: Demonstrate with samples an ability to produce packed copper-coated fibers with a bulk density of at least 50% of maximum theoretical bulk density of the copper-coated fibers with no degradation, and preferably improvements, in dissemination efficiency. Copper-coated graphite fibers are available commercially for this effort and should be cut to a length of one centimeter. (5) 100-gram samples shall be provided to ECBC for evaluation. Demonstrate the processes will improve performance for both nickel- coated and copper-coated fibers through the use of accelerated-aging storage techniques. Demonstrate that the process is scalable by providing 4 1-kg samples of each of the two improved bulk density packaged metal-coated fibers 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 concept 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 grenades and other munitions are needed to reduce the current logistics burden of countermeasures to protect the soldier and associated equipment. This technology could have application in other Department of Defense interest areas including high explosives, fuel/air explosives and decontamination. Improved separation techniques can be beneficial for all powdered materials in the metallurgy, ceramic, pharmaceutical and fuel industries. Industrial applications could include electronics, fuel cells/batteries, furnaces and others.

REFERENCES:
1. Bohren, C.F.; Huffman, D.R.; Absorption and Scattering of Light by Small Particles; Wiley-Interscience, New York, 1983.

2. Embury, J; Maximizing Infrared Extinction Coefficients for Metal Discs, Rods, and Spheres, ECBC-TR-226, Feb 2002, ADA400404, 77 Page(s)

3. Alyones S, Bruce CW, and Buin AK. "Numerical Methods for Solving the Problem of Electromagnetic Scattering By a Thin Finite Conducting Wire." IEEE Transactions on Antennas and Propagation 55.6: 1856-1861, 2007.

4. Bruce, CW., et al. "Millimeter-Wavelength Investigation of Fibrous Aerosol Absorption and Scattering Properties." Applied Optics 43.36: 6648-6655, 2004.

5. Waterman PC, "Scattering, Absorption and Extinction by Thin Fibers", J. Opt. Soc. Amer., vol. 22, no. 11, pp. 2430-2441, 2005

6. Hart M and Bruce CW, "Backscatter Measurements of Thin Nickel-Coated Graphite Fibers," in IEEE Transactions on Antennas and Propagation, vol. 48, no. 5, pp. 842-843, 2000.

7. Johnson S, Obscurant Applications, ISN Review, MIT, June 2012.

8. Burns A, “Means for Packaging and Dispensing Chaff,” US Patent 3,500,309, March 1970

KEYWORDS: metal-coated fibers, prolonged storage, microwave, packing, aerosolization, obscuration

A20-057 TITLE: Development of an Infrared Obscurant Produced In Situ from a Combat Vehicle

TECHNOLOGY AREA(S): Materials/Processes

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop a means to produce an infrared obscurant in situ from a combat vehicle.

DESCRIPTION: The Army is considering reviving the Vehicle Engine Exhaust System (VEES), which vaporizes fuel (diesel, when VEES was first introduced in the 1980's), by injecting it into the engine exhaust. The diesel recondensed immediately upon contact with ambient air, forming a dense white cloud. VEES did not work with JP8, and is also limited to primarily the VIS portion of the spectrum. Since that time, there has been a proliferation of sensors operating in the infrared. The objective of this topic is to develop an infrared obscurant that is produced in situ from the vehicle exhaust. It is suggested that the fuel be modified or have an additive which will react with the fuel upon extreme heating, or react upon exposure to air to produce the desired IR obscurant.

To address this requirement, the effort must identify the particles that will attenuate energy in the infrared portion of the electromagnetic spectrum. Generally speaking, higher performing particles are either flake or fiber shaped with high aspect ratio (approx. major dimension 3-5 um, minor dimension 10-50 nm) and high electrical conductive (on order of copper). Successful product will have an extinction coefficient of at least 1 m2/g covering the 3-5 um range and the 8-12 um range of the EM spectrum.

PHASE I: Outline then demonstrate the reaction chemistries necessary to produce an infrared obscurant using the on board vehicle exhaust of an existing combat vehicle. Demonstrate the infrared performance of the obscurant through modeling or chamber measurements. Effort may require a scaled system to demonstrate capability of producing IR obscurant through effluent stream. Continuous operation for at least 30 min without "gumming" or "fouling" of the exhaust system or otherwise adversely affecting engine performance is required.

PHASE II: Fabricate and install a working prototype on an M1 tank or M2 Bradley fighting vehicle. Demonstrate a feed-rate of at least one gallon per minute, while maintaining an aerosol cloud with an extinction coefficient of at least 1 m2/gm across the 3-5 and 8-12 um EM range. Continuous operation for at least 90 min without "gumming" or "fouling" of the exhaust system or otherwise adversely affecting engine performance is required.

PHASE III DUAL USE APPLICATIONS: Develop a production capability to produce thousands of gallons of performance mixture. If modifications to the exhaust are necessary, develop a low-cost protocol to retrofit the existing systems to accommodate the reaction parameters.

REFERENCES:
1. Embury J., Maximizing Infrared Extinction Coefficients for Metal Discs, Rods, and Spheres, ECBC-TR-226, Feb 2002, ADA400404, 77 Page(s)

2. Mishra, P.K., Role of Smokes in Warfare, Defence Science Journal, Vol 44, No. 2, Apr 1994, pp 173-179

3. Tedeschi, S., Improving Aerosol Dispersion Through a Fundamental Understanding of Interparticle Forces, http://etd.fcla.edu/UF/UFE0021643/tedeschi_s.pdf

4. Embury, J.; Walker, D.; Zimmerman, C., Screening Smoke Performance of Commercially Available Powders 1. Infrared Screening by Graphite Flake, Jul 1993, DTIC AD-A272 461

KEYWORDS: infrared, obscuration, in situ, diesel fuel, extinction

A20-058 TITLE: Disseminating Obscurants at Mach I

TECHNOLOGY AREA(S): Materials/Processes

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop a process for packaging and aerosolizing particulate obscurant materials from a high speed munition. The scenario is that the munition will be traveling at MACH I when the obscurant payload is quickly released to create an aerosol cloud at a specific location. Modeling could better define the required dissemination time and the resulting cloud geometry. Phase I will focus on modeling and defining concept parameters. Phase II will expand the effort to include fabricating hardware and testing to demonstrate the concept.

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. The proliferation of threats to combat vehicles including ATGM's and RPG's, raises the stakes for the Warfighter. A low-cost, precision countermeasure to these threats will be critical in increasing the survivability of the Next Generation Combat Vehicle (NGCV).

Since this is a relatively new area of research for the Army, very little work has been performed so far. One of the difficult issues will be testing and evaluation of a fast moving munition; creative ideas are needed in the demonstration of the capability. Another issue may be a fast release of the obscurant to avoid a long, narrow cloud.

PHASE I: Develop a concept for packaging and disseminating a particulate obscurant material. Demonstrate with modeling what the resultant cloud would look like when released from a munition traveling at Mach 1. Assume an 80-mm diameter munition with a 1-kilogram payload of graphite flakes (Asbury Micro 850 or equivalent). Demonstrate with modeling how a cloud at least 5 meters in diameter and 10 meters long could be produced. If the concept will allow other obscurant materials, it will improve its utility.

PHASE II: Demonstrate the capability in the field. Provide 5 prototypes that will allow field evaluation of the resulting aerosol cloud. In addition, in Phase II, a design of a manufacturing process to commercialize the concept should be developed.

PHASE III DUAL USE APPLICATIONS: Integrate the design into a munition specified by the Army. Fast moving munitions would include rockets, missiles and grenades. This technology is probably specific to the Department of Defense, but there are other applications there.

With the emergence of the Army Chief of Staff's Modernization Priorities, this obscuration technology supports the NGCV. Other Army Modernization Priorities that could benefit from this technology effort include Long-Range Precision Fires, Future Vertical Lift Platforms, Air and Missile Defense Capabilities, and Soldier Lethality

REFERENCES:
1. Landau, L.D.; Lifshitz; Fluid Mechanics, Vol 6 (2nd Ed); Butterworth-Heinemann, 1987. ISBN 978-0-08-033933-7

2. Schlichting, H; Gersten, K.; Krause, E.; Oertel, C.; Boundary Layer Theory, 8th Edition; Springer, 2004. ISBN 3-540-66270-7

3. Cebeci, T.; Shao, J.; Kafyeke, F.; Computational Fluid Dynamics for Engineers; Springer, 2017

4. Chang, C.; Time-Accurate, Unstructured-Mesh Navier-Stokes Computations with the Space-Time CESE Method; AIAA Paper 2006-4780, presented at the 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Sacramento, CA, July 2006.

5. Tedeschi, S., Improving Aerosol Dispersion Through a Fundamental Understanding of Interparticle Forces, http://etd.fcla.edu/UF/UFE0021643/tedeschi_s.pdf

6. Embury, J.; Walker, D.; Zimmerman, C., Screening Smoke Performance of Commercially Available Powders 1. Infrared Screening by Graphite Flake, Jul 1993, DTIC AD-A272 461

7. Johnson S, Obscurant Applications, ISN Review, MIT, June 2012.

KEYWORDS: Mach 1, graphite flakes, dissemination, packing, aerosolization, obscuration

A20-059 TITLE: Mesoscale Model Capability Informed by Cemetitious Composite Microstructure

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: To develop computationally effective software for the prediction of concrete properties and their evolution in time based on constitutive materials.

DESCRIPTION: With increased frequency, military personnel in the field are required to build structures with concrete materials whose properties are not known and for which the available technical literature is insufficient to estimate these properties. This applies to a wide range of concrete mixes, from low-quality concrete manufactured from in-situ or indigenous raw material components to ultra-high-performance concrete designed for high-end applications such as the protection of sensitive and high value structures (e.g. embassies, command and control buildings, etc.). Hence, there is a need for computational tools that allow the prediction of the mechanical properties of concrete directly from the basic components used in the mix design through simulating the generation and formation of concrete. These tools need to be accurate enough to be used in practical design applications but, at the same time, might need to be simple enough to be operated by personnel in the field. By leveraging recent accomplishments and published research, the US Army seeks the further development of the foundation for such tools within the computational framework of finite element and meshfree methods [1], which have been validated in the simulation of concrete and concrete structures [2, 3, 4] subject to blast and penetration, as well as in the simulation of concrete subject to long term deterioration phenomena [5]. The desired product should be capable of receiving the mix design parameters for cements, cementious materials, and aggregates via a script or GUI based interface, and output model parameters for continuum level material models in meshfree and finite element codes. This effort will be limited to the concrete material at the meso-scale, and is not expected to include reinforcing bar, but may include fiber reinforcing.

PHASE I: Develop a framework for a microscale model informed directly by hydration simulation.Demonstrate this approach on a model system. Identify an approach to computational optimization to achieve desired performance characteristics to be demonstrated in Phase 2. Deliver a technical report including microscale model development, demonstration on model system, and conceptual approach for optimization tied to multi-scale modeling framework.

PHASE II: Develop an integrated approach of linked hydration, microscale, and multi-scale modeling. Develop an optimization routine to achieve desired performance characteristics. Demonstrate this approach on a variety of model material systems representing different types of concretes. Compare the predicted material behavior at all length scales and the continuum level response with experimental observations. Demonstrate linkages between a multi-scale enabled approach to directly inform continuum level constitutive model calibration for meshfree and finite element codes. Deliver updated software package with integrated microscale models and optimization algorithms. Deliver technical report showing use of these tools on variety of model concrete systems. Deliver training for ERDC computational mechanics team and software for integration into HPC platforms.

PHASE III DUAL USE APPLICATIONS: Develop a fully integrated software package for non-expert use with integrated optimization tools to achieve target/goal performance characteristics with microscale models and multi-scale framework running in background. Software should provide outputs that can directly calibrate continuum level material models for weapons effects codes. Deliver integrated software system, technical report of finding including demonstration of technology on real work problems in blast, penetration, and quasi-static loading under a variety of conditions (i.e., study boundary value problems with experimental validations), transition software tools to HPC environment, and provide training for ERDC users.

REFERENCES:
1. G. Cusatis, D. Pelessone,A. Mencarelli. Lattice discrete particle model (LDPM) for failure behavior of concrete. I: Theory. Cement and Concrete Composites, 33(9), pp.881-890. 2011.

2. J. O'Daniel. Recent ERDC Developments in Computationally Modeling Concrete Under High Rate Events. Military Aspects of Blast and Shock (MABS 21), Jerusalem, Israel, October 2010.

3. M. Chandler, W. Lawrimore, M. Edwards, J. Shannon, J. O'Daniel. Mesoscale modeling of cementitious materials : phase I. ERDC GSL TR-19-25, Vicksburg, MS, 2019.

4. J. Smith, G. Cusatis, D. Pelessone, E. Landis, J. O'Daniel, J. Baylot. Discrete modeling of ultra-high-performance concrete with application to projectile penetration. International Journal of Impact Engineering, 65, pp.13-32. , 2014.

5. R. Rezakhani, M. Alnaggar, and G. Cusatis. Multiscale Homogenization Analysis of Alkali–Silica Reaction (ASR) Effect in Concrete. Journal of Engineering, 2019.

KEYWORDS: cement hydration, concrete modeling, indigenous concrete, material by design, material optimization, multi-scale modeling, ultra-high performance concrete

A20-060 TITLE: Detection and Classification of Small Moving Objects Floating in/on Water Using Long Wave Infrared Imaging Polarimetry or Combination of Radio, Laser Detection and Ranging Radar Technologies

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop sensor technologies with object recognition capabilities that can identify and distinguish, count and geographically locate small objects (<3 inches to >3 feet) floating in riverine environments using long wave infrared imaging polarimetry or a combination of radio, laser detection and ranging radar technologies for above and below water detection.

DESCRIPTION: Technologies with object detection capabilities sensitive enough to identify fast moving objects floating on the surface of water (or just below the surface) can offer important capabilities to understand the environment, upstream activities, and add to competencies for future military readiness and the warfighter. In this way micro-object detection can be used to inform warfighter threat avoidance, maneuverability and mobility. To meet the operational challenges and emerging dangers of the future the armed forces must be able to detect threats quickly and precisely. Because floating river debris is varied, generally comprised of small objects, often fast-moving, and complicated by the refractive properties of light on water, it requires quick and exacting sensor recognition capabilities. Sensors with this type of fidelity have potential for use by soldiers in theater as part of their protection system gear, and in military vehicles and sea faring vessels to identify objects on land and floating on the surface of water that pose a threat.

Sensors with object detection capabilities are an emerging technology currently used to service a number of efforts including self-driving cars, autonomous maze solving robots, detection of large surfaces on the bottom of the ocean and for the commercial fisheries, the ability to identify fish. However, this capability has not yet been fully exploited for accurate small object detection. Developing the technology proposed here will introduce new methods for greater accuracy of small object identification in complex environments both on land and at sea.

The goal here is to innovate methods for small object detection in the complex and fast moving environments of riparian landscapes. This effort should consider long wave infrared imaging polarimetry or a combination of radio, laser detection and ranging radar technologies for optimal above- and below-water object detection.

The method should be able to distinguish small objects, identify debris quantities and types and geographically locate individual debris materials. The desired solution is a technology that can be used by the warfighter on land and at sea to advance current capabilities and increase security.

PHASE I: Develop a basic proof-of-concept capability, in a stand-alone prototype, with sensor capabilities to identify a limited number of small objects commonly found floating in riverine environments, and count and geographically locate individual items of debris. Development and testing of initial prototype can be done in a lab environment with a small pool of still water (at least 2 feet deep and several feet across).

PHASE II: The contractor will expand capabilities of the prototype developed in Phase 1. This prototype version should work in the field on small streams (several feet deep with surface areas of a few feet to yards across). Capabilities should include the ability to identify and distinguish between a greater number of objects, record numbers of each item sighted and geospatially locate each material.

PHASE III DUAL USE APPLICATIONS: The contractor will create a sensor product suitable for use on large rivers (yards across and several feet deep) and military vehicles and sea faring vessels with the expanded capabilities developed in Phase 2. Products will be applied to existing systems and contain a prototype for classification, training and safety certifications, and business case analysis for future acquisition activities.

REFERENCES:
1. Harchanko J., Pezzaniti L., Chenault D., Eades G.(2008). Comparing a MWIR and LWIR polarimetric imager for surface swimmer detection. Proceedings of SPIE – The Internatrional Society for Optical Engineering. Retrieved from http://www.polarissensor.com/app/uploads/2016/04/MWIR-versus-LWIR-for-Surface-Swimmer-Detection.pdf

2. Hill G., Hjemlstad L. (2016). A Detection System for Detecting an Object on a Water Surface. 15/031,022. United States. Retrieved from https://patientimages.storages.googleapis.com/oo/4b/f8/7b27a5e479fe3c/US20160266247A1.pdf

3. Lin, TY., Maire, M., Belongie, S., Bourdev, L. Girshick, R., Hays, J., Perona, P.. Ramanan, D., C. Zitnick, L., Dollar, P. (2015). Microsoft COCO: Common Objects in Context. ECCV. Retrieved from https://arxiv.org/pdf/1405.0312.pdf

4. Rahul Kumar, Peni Jitoko, Sumeet Kumar, Krishneel Pillay, Pratish Prakash, Asneet Sagar, Ram Singh,Utkal Mehta. (2017). Maze solving robot with automated obstacle avoidance. Procedia Computer Science 105. 57 – 61. Retrieved from https://www.researchgate.net/publication/31439978_Maze_Solving_Robot_with_Automated_Obstacle_Avoidance/fulltext/58b6e725a6fdcc2d14d6e6cb/314139978_Maze_Solving_Robot_with_Automated_Obstacle_Avoidance.pdf?orgin=publicaton_detail

5. Thompson, J. (2017). Maritime Object Detection, Tracking, and Classification Using Lidar and Vision-Based Sensor Fusion. Dissertations and Theses. 37. Retrieved from https://commons.erau.edu/cgi/viewcontent.cgi?article=1376&context=edt

6. University of Rhode Island. (2019). Discovery of Sound in the Sea: How is Sound Used to Find Objects on the Ocean Bottom? Retrieved from https://dosits.org/people-and-sound/navigation/how-is-sound-used-to-find-objects-on-the-ocean-bottom/

7. University of Rhode Island. (2019). Discovery of Sound in the Sea: How is Sound Used to Identify Fisb? Retrieved from https: https://dosits.org/people-and-sound/fishing/how-is-sound-used-to-identify-fish/

8. Wang, Y., Wang, D., Lu, Q., Luo, D., and Fang, W. "Aquatic Debris Detection Using Embedded Camera Sensors". Sensors(Basel). 15(2): 3116-3137. Retrieved from Https://www.mdpi.com/1424-8220/15/2/3116/htm

9. Waymo. (n.d.). Technology. Retrieved from http://waymo.com

KEYWORDS: Sensors, Object-detection, machine learning, intelligence, moving water, fusion, GPS

A20-061 TITLE: AI Based Autonomous Agents that Possess Human-like Cognitive Skills in a Real-Time Strategy Game Environment

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop computer algorithm based autonomous artificial agents that operate in a virtual game environment and which possess human-like cognitive skills to learn complex human tasks (i.e., land navigation, strategy, course of action analysis, etc.), and function in varying scales from individual agents, small teams, to large groups that function in a coordinated fashion both cooperatively and in an adversarial manner with other agents.

DESCRIPTION: Current state-of-the-art artificial agents are performing human-like activities at or above professional level humans in adversarial real time strategy games such as Dota 2 and StarCraft II. These agents have successfully demonstrated a variety of human-like abilities such as learning, adapting, strategizing, and decision making in extremely complex adversarial games. However, current methods for training autonomous agents for 3D simulations involve utilizing game statistics, domain knowledge, and immense agent training time, which limit their applicability to more complex problem domains. Additionally, these approaches fall short in many areas when considering the ease in which humans perform even the most complex cognitive activities. Shortfalls in capabilities include (1) large computational costs associated with deep reinforcement learning reduce the feasibility of training large multi-agent systems, (2) the agents do not possess temporal memory or long term memory to keep, maintain, or improve upon skills, (3) agents cannot perform complex long term planning instead relying on extensive exploration to learn a policy and (4) the lack of planning reduces the capability of the agents to effectively cooperate in multi-agent scenarios.
The following are the desired innovative and technical features to achieve the topic objective:
a)Function over long time horizons: up to 24 hours, in a large, high-dimensional, continuous observation/action space, with sparse feedback and delayed reward. Current state-of-the-art agents in Dota 2 perform over an average match length of 35 minutes. We are seeking agents that select optimum actions despite delayed rewards (action feedback) over long time horizons.
b)Cooperative planning: agents that are able to plan and coordinate policies with other agents to cooperatively complete a task.
c)Online learning: agents that are able to learn from immediate experiences without catastrophic forgetting of important learned information. This includes the ability to adjust to changing environment and task circumstances.
d)Memory: agents that possess temporal memory. Example: humans can navigate to desired location and easily retrace their return path back to the starting point without photographically memorizing all features along the way.

PHASE I: Provide a written innovative technical approach beyond state-of-the-art that demonstrates feasibility of an autonomous agent to learn performing complex tasks in OpenAI's Neural MMO: A Massively Multiagent Game Environment (https://openai.com/blog/neural-mmo/). Technical approaches must demonstrate feasibility of meeting one or more of the above stated technical features (a-d, above).

PHASE II: Develop algorithms which demonstrate autonomous agents that perform a variety of complex tasks and scale to large sets of teams to be identified in Phase I and with an ability to compete in adversarial games that possess all of the required technical features: agents that function over time horizons of at least twenty four hours, perform cooperative planning, online learning without catastrophic forgetting, and possess temporal memory. These agents must function in OpenAI's Neural MMO: A Massively Multiagent Game Environment (https://openai.com/blog/neural-mmo/). Agent algorithms must be capable of being trained on a desktop or server class computer with a minimum of a 16 core CPU at 99th percentile performance according to https://cpu.userbenchmark.com/ and a minimum of 8X GPUs with 99th percentile performance according to https://gpu.userbenchmark.com/. The agent algorithm must achieve a technical maturity of

PHASE III DUAL USE APPLICATIONS: Human-like agents that can perform human tasks at expert level or higher can be used for commercial factory automation, self-driving vehicles, and robot navigation. Government applications would include large scale virtual or constructive wargame simulations, cooperative drone swarms, and large-scale military logistics planning and support.

REFERENCES:
1. Trapit Bansal, Jakub Pachocki, Szymon Sidor, Ilya Sutskever, Igor Mordatch, “Emergent Complexity via Multi-Agent Competition”, conference paper at ICLR 2018, arXiv: 1710.03748. https://arxiv.org/pdf/1710.03748.pdf

2. Kenneth O. Stanley, Jeff Clune, Joel Lehman, and Risto Miikkulainen, “Designing neural networks through neuroevolution”, Nature Machine Intelligence, Volume 1, pages 24–35 (2019) https://www.nature.com/articles/s42256-018-0006-z.pdf

3. Greg Wayne, Chia-Chun Hung, David Amos, Mehdi Mirza, Arun Ahuja, Agnieszka Grabska-Barwinska, Jack Rae, Piotr Mirowski, Joel Z. Leibo, Adam Santoro, Mevlana Gemici, Malcolm Reynolds, Tim Harley, Josh Abramson, Shakir Mohamed, Danilo Rezende, David Saxton, Adam Cain, Chloe Hillier, David Silver, Koray Kavukcuoglu, Matt Botvinick, Demis Hassabis, Timothy Lillicrap, “Unsupervised Predictive Memory in a Goal-Directed Agent”, arXiv: 1803.10760. https://arxiv.org/pdf/1803.10760.pdf

4. Sainbayar Sukhbaatar, Emily Denton, Arthur Szlam, Rob Fergus, “Learning Goal Embeddings via Self-Play for Hierarchical Reinforcement Learning”, arXiv: 1811.09083. https://arxiv.org/pdf/1811.09083.pdf

5. Piotr Mirowski, Razvan Pascanu, Fabio Viola, Hubert Soyer, Andrew J. Ballard, Andrea Banino, Misha Denil, Ross Goroshin, Laurent Sifre, Koray Kavukcuoglu, Dharshan Kumaran, and Raia Hadsell, “Learning to Navigate in Complex Environments”, arXiv: 1611.03673. https://arxiv.org/pdf/1611.03673.pdf

6. Kyle Hsu, Sergey Levine, Chelsea Finn, “Unsupervised Learning via Meta-Learning”, published as a conference paper at ICLR 2019, https://openreview.net/pdf?id=r1My6sR9tX

KEYWORDS: Artificial Intelligence, Deep Learning, Reinforcement Learning, Real-time Strategy Games, Meta Learning, and Deep Neuroevolotion.

A20-062 TITLE: Atmospheric Water Harvesting Tool

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Develop novel technology to efficiently harvest drinking water for individual warfighter application, where an expedient, lightweight, reliable, safe, and low or no power technique is critically needed.

DESCRIPTION: Clean water scarcity is a significant challenge to the Warfighter, particularly in arid and desert climates. Improved water self-sufficiency, which will supply safe potable water to a small squad without the logistical burden of re-supply, is highly desirable and is a priority for all Services. Supporting Service documentation demonstrates the need to improve access/procurement technologies for clean drinking water; atmospheric water harvesting technologies can fill this capability gap.3 There are 12,800 trillion liters of water available in earth’s atmosphere.4 According to the US Army Combined Arms Support Command Force Development Directorate’s Water Planning Guide, in both conventional theater tropical or arid environments the required amount of drinking water for sustainment is 3.3 gal / person / day (12.5L / person / day).4 Emerging materials and technologies in water harvesting such as metal-organic frameworks (MOF) can extract from this renewable resource in order to meet warfighter needs for clean, fresh drinking water.5 Strategies/technologies for water harvesting i.e., metal-organic frameworks, hydrogels, and other materials suitable for drinking water shall be identified, conceptualized and tested. A high fidelity breadboard model shall be evaluated in a simulated environment to validate the viability of the approach. It is desired that this small, portable individual atmospheric water-harvesting unit would support the individual warfighter, generating up to 14L of water / day to augment soldier hydration at the point of need. For example, the unit could use novel sorbent materials (such as MOFs, hydrogels) to capture water vapor at low relative humidity conditions (under 40% relative humidity (RH)) and then condense and collect the captured water, generating potable drinking water. If the unit is powered, it shall consume less than 0.5 kg of fuel daily and be capable of operating day or night with little to no noise emission and not generate an undesirable visible or thermal signature. Additionally, the proposed weight of the unit (<20lbs) is less than the weight of carrying 14L of water into the field (~30.8lbs). This would reduce weight and allow for multi-day missions without resupply. This capability would also protect warfighters from illness due to intentional or unintentional water contamination since the water would be self-generated from the atmosphere. This technology could also be scaled up to provide self-generated potable water for the squad level in the field.

The design shall be intrinsically safe (possess anti-microbial features, capable of being sanitized and/or disposable), provide hygienic functionality, convenience, and affordability (i.e. target production cost of $100 or less). The use of consumables or supplemental materials shall be avoided and the device shall also operate in environmental extremes (20F to 125F). The technology should provide a novel personal water harvesting capability that improves water production capabilities, increases self-sufficiency and reduces the requirement to transport water to the warfighter, ultimately enhancing maneuverability, security and readiness.

PHASE I: Develop a proof of concept capable of demonstrating the performance outlined above. Establish the feasibility and practicality of the proposed design, materially demonstrate and validate the concept through testing. A preliminary cost analysis be completed based on projected scale-up and manufacturability considerations. A final report shall be delivered that specifies how requirements will be met (including mitigation of risks associated with factors limiting system performance). The report will detail the conceptual design, performance modeling and associated drawings (Solidworks® format), scalability of the proposed technology with predicted performance, safety and human interface (MANPRINT) factors, and estimated production costs. The projected technical readiness level (TRL) shall achieve a TRL of 3 and provide a clear path to Phase II/III and follow-on commercialization.

PHASE II: Refine the technology developed during Phase I in accordance with the goals of the project. Fabricate and demonstrate an advanced prototype for the target warfighter application, verifying that the desired performance is met. Provide a report, associated drawings and control software/source code, if applicable, documenting the theory, design, component specifications, performance characterization, projected reliability/maintainability/cost and recommendations for technique/system implementation. Deliver a full scale prototype to support Army technical, operational, environmental and safety testing in the target application by the end of Phase II. An updated production cost analysis shall be completed and design for manufacture considerations shall also be projected to support advancement of TRL and associated Manufacturing Readiness Level (MRL). The operational characteristics of the water harvester shall be provided to validate the feasibility of the approach and support transition to military and commercial applications (Phase III).

PHASE III DUAL USE APPLICATIONS: The proposed technology innovation and associated manufacturing capability will overcome the present technology gap and be rapidly transitioned to both military and commercial applications, where a self-contained, high efficiency, and long life technology will lead to renewable personal water harvesting unit for individual warfighters or squad units, as appropriate. The Phase III is expected to advance the proposed innovation to a TRL of 7 or higher, supporting a system demonstration in a relevant environment in the hands of the Soldier. As a progression of the Phase I that serves to prove out the novel development proposed, the Phase II should result in a full scale prototype deliverable, which will serve to validate the performance, feasibility and overall benefit to be realized through the proposed development initiative. Ultimately, the technology will be transitioned to the Squad or individual Soldier, where high efficiency, long life, and low cost technology is needed to maximize the performance, lethality and security of the Soldier through optimum hydration and nutrition in all operating environments. The Phase III represents concurrent (unfunded) commercialization of the technology that is expected to provide economy of scale, logistic, and other benefits that can be attributed to the proposed development.

REFERENCES:
1. Farshid Bagheri “Performance investigation of atmospheric water harvesting system” Water Resources and Industry 20 (2018) 23-28. https://www.sciencedirect.com/science/article/pii/S2212371717300744

2. Kim, Hyunho, et al. "Water harvesting from air with metal-organic frameworks powered by natural sunlight." Science 356.6336 (2017): 430-434. https://science.sciencemag.org/content/356/6336/430

3. Army Functional Concept for Sustainment 2020-2040, “TRADOC Pamphlet 525-4-1” February 2017. https://adminpubs.tradoc.army.mil/pamphlets/TP525-4-1.pdf

4. United States Army Combined Arms Support Command, Force Planning Directorate, “Water Planning Guide” 25 November 2008. https://quartermaster.army.mil/pwd/Publications/Water/Water_Planning_Guide_rev_103008_dtd_Nov_08_(5-09).pdf

5. Montain, Scott J. and Ely, Matthew, “Water Requirements and Solider Hydration”, Military Quantitative Physiology: Problems and Concepts in Military Operational Medicine, Chapter 7, Textbooks of Military Medicine (2012). https://ke.army.mil/bordeninstitute/published_volumes/mil_quantitative_physiology/QPchapter07.pdf

KEYWORDS: Soldier sustainment, Personal water harvester, Drinking water source, Manufacturing Processes, Manufacturing quality

A20-063 TITLE: Brain-Inspired Few-Shot Object Recognition

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop a brain-inspired artificial neural network algorithm that performs accurate and robust object detection.

DESCRIPTION: Artificial Intelligence has yet to surpass the human brain in terms of training time: even the best algorithms require huge datasets that train carefully-tuned models over a long period of time. Current state-of-the-art artificial neural networks for image identification, called Convolutional Neural Networks (CNNs), are achieving at, or higher, than human level performance in recognizing 2D images from the open source ImageNet database (http://www.image-net.org/) of labeled images (plant, animals, etc.) which benchmarks performance. CNN performance in ImageNet data for standard color photos, greyscale, and photos based on textures (i.e.; elephant skin) are on par or slightly better than human performance. CNN performance degrades substantially with images of object silhouettes (black object with white background) and edges (image features represented with only lines), when objects under observation are small in scale relative to surrounding area, and when object viewpoint, rotation, size, and illumination vary. CNN training on ImageNet data requires on the order of 1000 examples per object class yet humans need to see a new object only once or twice and it becomes instantly recognized at a later time.
We are seeking brain-inspired artificial neural network algorithms that can meet the performance objectives of recognizing objects in images from less than 10 training examples with 90% confidence of object identification under a full range of image observation conditions to include varying scale, size, illumination (full sunlight to low light), occlusion (from zero to 90% in both height/width increments of 15%), and rotation (in increments of 30°). A virtual 3D environment to train and demonstrate viability of the proposed algorithm is desired such as the Unity open source game engine (https://store.unity.com/products/unity-personal?_ga=2.145300465.433590269.1559218374-1672088338.1559218374). It is desired that artificial neural network algorithm be developed with open source development code such as TensorFlow (https://www.tensorflow.org/) or Python (https://www.python.org/). It is desired to have a high resolution color video camera (https://www.blackmagicdesign.com/products/blackmagicmicrostudiocamera4k) with a minimum of 3840 x 2160 pixels be used to observe raw pixels from the 3D virtual environment to train and demonstrate feasibility and performance of the algorithm. Novel approaches to train for object recognition that realistically emulate the human vision system (e.g., stereopsis, foveation, etc.) are desired if a breakthrough in capability is feasible.

PHASE I: Demonstrate in the Unity game engine environment an innovative and beyond state-of-the-art approach that demonstrates a viable and feasible technical approach to meet the topic objectives.

PHASE II: Develop, demonstrate, and test object recognition algorithms that meet the topic objective. Object recognition algorithms will be tested incrementally against the Common Objects in Context (COCO), http://cocodataset.org/#home, and ImageNet, http://www.image-net.org/, image data sets to establish benchmark performance against state-of-the-art. Image data sets will be developed to be capable of being rendered to meet the topic objectives for challenging object recognition training observations (scale, illumination, etc.). Object recognition algorithms will be matured to a TRL 5 by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Robust object detection would be a boon for safer commercial autonomous self-driving vehicles, drones, and robots. Military applications would include target identification, combat friend or foe identification, and for live force-on-target training at combat training centers

REFERENCES:
1. D. Tsao, “How the Brain’s Face Code Might Unlock the Mysteries of Perception”, https://www.nature.com/articles/d41586-018-07668-4 , December 11, 2018

2. L. Chen, S. Singh, et al., “Supporting Information Appendix: Brain-Inspired Automated Visual Object Discovery and Detection”, https://authors.library.caltech.edu/91893/2/pnas.1802103115.sapp.pdf

3. "New AI system mimics how humans visualize and identify objects”, https://samueli.ucla.edu/new-ai-system-mimics-how-humans-visualize-and-identify-objects/

4. R. Geirhos, P. Rubisch, et al., “ImageNet-trained CNNs are biased towards texture; increasing shape bias improves accuracy and robustness”, ICLR 2019, https://arxiv.org/pdf/1811.12231.pdf, GitHub models, data, and code: https://github.com/rgeirhos/texture-vs-shape

5. Hossein Adeli, Gregory Zelinsky, “Deep-BCN: Deep networks meet biased competition to create a brain-inspired model of attention control”, IEEE Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, 2018, pp. 1932-1942, http://openaccess.thecvf.com/content_cvpr_2018_workshops/papers/w39/Adeli_Deep-BCN_Deep_Networks_CVPR_2018_paper.pdf

6. "Deep Predictive Coding Network with Local Recurrent Processing for Object Recognition”, https://papers.nips.cc/paper/8133-deep-predictive-coding-network-with-local-recurrent-processing-for-object-recognition.pdf

KEYWORDS: Object Recognition, Convolutional Neural Network, and Human Vision

A20-064 TITLE: Reduced Signature Powered Parafoils

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop and demonstrate innovative methods, materials, mechanisms and/or technologies to reduce the acoustic, visual, IR, and/or other radar signatures of traditional, commercial off the shelf powered parafoil systems for personnel and/or cargo.

DESCRIPTION: The U.S. Army Combat Capabilities Development Command, Soldier Center (CCDC-SC), Aerial Delivery Directorate (ADD) is looking to investigate innovative approaches for powered parafoil that have a reduced signature compared to traditional, commercial off the shelf systems (COTS). Paratrooper and aerial resupply operations are typically conducted from aircraft dropping either guided or unguided parachutes; meaning the range is determined by the aircraft’s altitude, parachute’s glide slope, and weather conditions. Adding a motor to the system can increase its range, thereby reducing the aircraft’s signature and, possibly, eliminate the need for airdropping the system. Increasing the range allows for further aircraft standoff, keeping aircraft away from the enemy. Without the need for an aircraft, powered parafoils enable ship to shore or ground to ground resupply. Once on the ground, a current parachute and JPADS systems are the responsibility of the Soldier but with the ability for a powered parafoil take off and autonomously return to launch; the responsibility of the system is lifted from the Soldier and powered parafoil can be refitted to be used again. Given the capability of a powered parafoil to autonomously and covertly deliver itself to a Soldier, the Soldier could leave an area without detection and without carrying all the equipment for flight throughout the mission. Powered parafoils can have a greater mass delivered to cost compared to a Unmanned Aerial System (UAS) but can often be detected by the noise from the motor and propeller and their slowly moving radar/IR signatures. CCDC-SC, ADD is interested in technologies that can reduce one or more aspects of the vehicle's signature, with particular interest in reducing the acoustic, visual, IR, or other radar signature. Specific manned and/or unmanned vehicles have not been identified, so technologies that have a more general application across a range of systems are of interest. Final system should be scalable for payloads from 25 lbs. to 500 lbs. and capable of traveling 500 km, in zero wind conditions. Reduction in acoustic, visual, IR, other radar should be shown compared to an unmodified COTS system at 100, 500, and 1000 feet, showing a minimal 20% reduction. Modifications should not increase the system procurement to more than 40% original cost.

PHASE I: Identify multiple solutions to reducing the signature of powered parafoils which would advance the current state of the art. Develop detailed analysis of predicted performance. If parafoil rigging materials (ropes, cords, suspension lines, slings, etc.) foreign to aerial delivery applications are used, conduct stress/strain, porosity and yield testing on swatches of material to quantify essential material properties. Phase I deliverables include a report detailing all procedures employed in the research, all results of tests conducted, all potential technologies reviewed, samples of materials or small scale prototypes, milestones to be accomplished in Phase II, a recommended path forward and cost estimate to a) reduce the signature of a COTS technology or b) design of a new technology to replace a COTS technology.

PHASE II: Design and construct prototype systems using the material and/or design identified in Phase I; prototypes should be capable of lifting at least 100 lbs. to ensure signature is comparable to final product. Demonstrate operation of the prototype systems in a relevant environment. This could entail releasing the system from either a fixed or rotary wing aircraft and/or ground take-off/landing to assess airworthiness in the airdrop environment and quantify usability and survivability of the solution. Prototype may have automated guidance, remote control or manned operator and repeat testing of the prototype systems to assess operational life of the system. Phase II deliverables include any prototype devices constructed, a technical data package detailing the material/methods/mechanism designs, a demonstration of the prototype system/device to include dynamic airdrops of the system, and a report detailing all Phase II work, a recommended path forward, and updated cost estimate to a) reduce the signature of a COTS technology or b) design of a new technology to replace a COTS technology for a range of quantities.

PHASE III DUAL USE APPLICATIONS: Powered parafoils can enable applications that today are not feasible. They require minimal infrastructure, have the ability to enter and depart locations that classic ground, fixed or rotary wing aircraft have difficulty reaching or be considered a high risk. They can move a considerable amount of mass, over greater distances, at a lower cost than an alternative UAS. With total loss of power, parafoil will return mass to the ground at a lower descent rate, compared to a multi-rotor UAS, enabling entrance into urban areas. Reducing the signature will allow for covert missions or exfiltration at minimal detections risks and great distances. Reduced signature will obscure the sources of resupply as the parafoil could only be detected at the last moments of flight. While powered parafoils are already used, quieter engines can be used for less unobtrusive nature studies. Given the capability of a powered parafoil to autonomously and covertly deliver itself, anyone could then be exfiltrated without detection. With drone delivery currently passing regulatory hurdles, this technology could minimize the impact of hefty deliveries into everyday life.

REFERENCES:
1. Designing For Internal Aerial Delivery In Fixed Wing Aircraft, MIL-STD-1791, 23 Oct 2017 http://everyspec.com/MIL-STD/MIL-STD-1700-1799/MIL-STD-1791C_55770/

2. Army Modernization Priorities https://www.army.mil/standto/2018-01-16

3. FAA Powered Parachute Handbook, FAA-H-8083-29; 2007 https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/powered_parachute_handbook.pdf

4. https://en.wikipedia.org/wiki/Powered_parachute

KEYWORDS: Reduced Signature, Powered Parafoils, Parachute, IR, acoustics

A20-065 TITLE: Haptics-enhanced Augmented Reality Training System for Care Under Fire

TECHNOLOGY AREA(S): Information Systems

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

OBJECTIVE: The purpose of this SBIR is to develop an Augmented Reality (AR) training system that trains Care Under Fire concepts. Combat Medic and Combat Lifesaver trainees do not currently have the capability to train how to move from a “Soldier First” context and engage an enemy, to providing injury care, and potentially back to engaging the enemy, in a virtual world. While haptics capabilities have been integrated to a small scale with virtual reality training devices, they have not been integrated in an AR environment, which provides much more realism for some tasks requiring weighted objects (e.g., wounded soldier). The purpose of this effort is on the haptics capability, and not the development of a combat casualty care simulation.

DESCRIPTION: Current Care Under Fire training does not allow for effective transition from a Soldier First context to a caregiver context, and back again. Integrating haptics capabilities into an AR training system will allow trainees to participate in both contexts with much more realism than allowed by mock rifles. We are seeking a haptics-enabled AR system that provides virtual representations of some entities (e.g., enemy avatars), real-world entities where appropriate (e.g., weighted patient simulators), and augmented representations of other entities (e.g., bleeding wounds on patient simulators, devices in a real-world medic bag).

PHASE I: Phase I should include a detailed study of historical Care Under Fire situations and developing a flow of how to move a trainee through a “crawl-walk-run” training evolution. With this flow, the offeror should consider how and where to insert Virtual, Augmented, and if necessary Mixed Reality training systems. Considerations of where haptics technology should be inserted, and why, should be noted (e.g., clearing a weapons misfire, feeling for a devices inside a medic bag while visually scanning for enemies).

The end result of Phase I should thus focus on two areas. The first area explores the Care Under Fire phase of Tactical Combat Casualty Care, and explains the important training elements. A flow moving a trainee from a simple evolution (e.g., no enemy action), to a more complex evolution (e.g., initial enemy action requiring the trainee to engage the enemy prior to caring for the injured) to the most complex evolution (e.g., initial engagement coupled with a weapon misfire, caring for the injured, and follow-on enemy action causing the trainee to set aside patient care to engage the enemy). The second area will explore haptics capability and its relevancy to the Care Under Fire training scenarios, with a description of how haptics can and should be integrated with virtual and/or augmented reality.

At the end of Phase I, offerors must present an estimate of the per-unit cost at the end of the first year, and end of the second year, of Phase II, should they be slected.

A simple feasibility demonstration should occur late in Phase I. This may take place at the developer’s facility.

Phase I should finalize with a working plan to mature these areas into a training system to be developed in Phase II. Included should be plans for how to obtain, procure, or reuse a virtual simulation – whether organic to the offeror, purchased from or subcontracted to another firm, or via government furnished information/property.

PHASE II: Phase II will result in a training system developed on the concepts explored in Phase I. Initial usability testing should be performed with relevant users (e.g., at a military training center). Based on enhancements from usability tests, a training effectiveness evaluation should be performed with military trainees (e.g., Army Medical Simulation Training Center, National Guard training site, equivalent Navy/Air Force/Marine Corps training site teaching Care Under Fire principles). Phase II should result in a working prototype training system and a final report that covers both training aspect considerations and technical considerations. At the end of both years of Phase II, offerors must present the government with updated estimates of per-unit cost. A deliverable of Phase II should be a technical data package listing all software and hardware, both commercial off-the-shelf and custom-developed, that comprise the final system. Licenses to allow for system usage for no less than one year after end of contract are also required in order to continue demonstration to potential transition partners. Finally, a users' guide and training manual should accompany the final delivery to allow for instructors to use the system.

PHASE III DUAL USE APPLICATIONS: The initial use for this technology will be to train military medical first responders who are trained as Warfighters first, Caregivers second. In much the same way, many local, state, and federal law enforcement officials (LEOs) are being trained to provide limited lifesaving skills (e.g., tourniquet application) during active shooter and similar events. A Phase III dual-use application would create a similar training system to support non-military LEOs in a tactical situation. As protocols differs from LEO and military, and even from one LEO entity to another, care should be taken to consider protocols during Phase III.

REFERENCES:
1. Ali, N. S., & Nasser, M. (2017). "Review of virtual reality trends (previous, current, and future directions), and their applications, technologies and technical issues" J Eng Appl Sci, 12, 783-789.

2. Karlsson, M. (2015). Challenges of designing augmented reality for military use. http://www.diva-portal.org/smash/get/diva2:823544/FULLTEXT01.pdf

3. Milham, L. M., Phillips, H. L., Ross, W. A., Townsend, L. N., Riddle, D. L., Smith, K. M., ... & Johnston, J. H. (2017). Squad-level training for Tactical Combat Casualty Care: instructional approach and technology assessment. The Journal of Defense Modeling and Simulation, 14(4), 345-360

4. Rashid, F. (2017). Use of VR technology and passive haptics for MANPADS training system. Naval Postgraduate School Monterey United States. https://calhoun.nps.edu/bitstream/handle/10945/56170/17Sep_Rashid_Faisal.pdf?sequence=1&isAllowed=y

5. Reitz, E. A., & Seavey, K. (2016). Virtual Dismounted Infantry Training: Requiem for a Dream. Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2016

KEYWORDS: Medical modeling and simulation, care under fire training, haptics, augmented reality

A20-066 TITLE: Vehicle Mounted Expandable Command Posts (VMECoP)

TECHNOLOGY AREA(S): Battlespace

OBJECTIVE: The mobility of tactical command centers and other key communication assets is a critical capability in future conflicts. To enable Soldier survivability, critical Command Post based assets will need to move freely and rapidly on the battlefield, increasing mission command capability. A VMECoP that can be expanded and torn down quickly would allow for short notice movement of the mission command capability, reduce vulnerabilities, and increase lethality. The expandable capability of this system is critical as non-expandable shelters provide limited square footage and reduce potential.

DESCRIPTION: U.S. Army's high-level objectives dictate that timely movement of mission command and tactical intelligence assets shall be prioritized. Forward mission command and tactical intelligence assets shall be mobile, achieving operational maneuverability in all environments and at a high operational tempo. Future Command Posts must have greater tactical mobility to support mission command in the current Mulit-Domain Battle. Specifically, the emplacement, erect/strike of the VMECoP must be completed in mere minutes.

Historically, the Army Standard Family International Standardization Organization (ASF ISO) expandable shelters have been utilized for a range of high value tactical functions, for example: Command/Control and Deployable Surgical Operating Theaters. These are transported to a site, off loaded with either 15K MHE or a special purpose vehicle. Once in position, the shelter is expanded, power is connected, and the desired mission performed. Tear down of the system would follow the reverse order of set up. Asset removal would again require a 15K MHE or special purpose vehicle. The process of moving an expandable shelter and its associated high value tactical system has historically been orchestrated with the coordination of 4 or more Warfighters, a 15K MHE or special purpose vehicle and careful coordination of all support equipment (power generation, power distribution, and environmental control units (ECUs)) which must be transported separately to support the capability.

The current ASF ISO Expandable Shelters conform to 8ft x 8ft x 20ft ISO shipping container envelope, as defined by ISO 668 Series 1 freight containers – Classification, dimensions and ratings. The current ASF ISO Expandable Shelters meet the structural requirements of ISO 1496-1 Series 1 freight containers – Specification and testing – Part 1: General cargo containers for general purposes. In the deployed configuration, the existing ASF ISO Expandable Shelter, 1 sided expandable provides 265 ft2 of interior space. Any proposed shelter would have to provide similar square footage. The common ISO interface of the existing shelters facilitates standardized material handling, transportation methods, and equipment integration, and would be required on any proposed design.

The proposed VMECoP solution shall meet the threshold requirements as shown in Table 1 below:

Table 1: Performance Metrics for Vehicle Mounted Expandable Command Posts - TABLE WILL BE UPLOADED WITH TOPIC

It is imperative that the proposed designs take into account both speed and Warfighter safety during deployment. Additionally, the stability of the expanded floor sections while in the deployed configuration is critical. If a powered assist is used to deploy the shelter, designs must consider the source to provide this power and its impact on the time required to achieve the basic deployment of the design. The current ASF ISO Expandable Shelters one side expandable should be considered as the baseline technology for this effort to improve upon.

The current Expandable ASF ISO Shelters can be shipped by road, rail, internal and external air transport, sea and moved via common MHE. Additionally the current Expandable AFS ISO Shelter can operate in conditions ranging -40F to 120F and survive exposure to temperatures from -70F to 160F. The one sided ASF Expandable Tactical Shelter provides a power/data entry panel and removable panels for a ducted ECU, but is not integrated with power generation assets nor ECU capability. Offers should consider proposing solutions incorporating power generation and ECUs systems as well. Innovation is encouraged when accounting for interfacing with, transporting and or integrating power generation and ECU equipment.

U.S. Army high-level objectives dictate that timely mission command and tactical intelligence shall be prioritized. Forward mission command and tactical intelligence assets shall be highly mobile, achieving operational maneuverability in all environments and at a high operational tempo. Command Posts must provide greater capabilities to support Warfighters in the current Multi-Domain Battlefield. Smaller, highly mobile, command posts are easier to conceal and move and, therefore, more survivable. A mobile, command post remains essential to command and control in future dispersed, decentralized, multi domain operations. It is also required to enable command from any location, assess the situation firsthand, make decisions rapidly, and influence people and operations to maintain or regain the initiative on a lethal battlefield.

As the objective is to increase Command Post capabilities, the proposed MMECoP design should exhibit the following characteristics:

- Shall meet or exceed the Threshold metrics established in Table 1.
- Shall be operationally deployable within an 8’ x 8’ x 20’ ISO 1C freight container envelope and requirements as defined by ISO 668.
- Shall meet CSC transportation requirements as defined by ISO 1496-1.
- Shall meet system weight objective values in Table 1.
- Shall have a pay load as stated in Table 1.
- Shall mitigate unsafe or hazardous conditions when shelter is deployed (set-up) while mounted on a vehicle.

- Shall exhibit mechanical stability of the expandable components when deployed.
- Shall not cause or shall mitigate unsafe of hazardous conditions when power generation and ECU equipment are in operation while the shelter is mounted on a vehicle.
- Shall minimize the logistical burden on the supply chain, and not require the transportation of unsafe or hazardous materials/chemicals.
- Shall interface with military power connectors. Current ASF ISO Expandable Shelters interface with 100A or 60A Class-L 208V 3-phase power connector (MIL-DTL-22992).
- Shall provide an interface for external data and communication systems on fixed end wall.
- Shall have an overall heat transfer coefficient less than or equal to 0.26 Btu/(h*ft2*°F) in the operational configuration. It is desired the overall heat transfer coefficient be less than or equal to 0.22 Btu/(h*ft2*°F) in the operational configuration.
- Shall interface with a logistically supported ECU: ducted 60K IECU and 60K FDECU.
- Designs solutions are not required to be an entirely rigid walled shelter system. Innovative approaches to fast deployment and strike are encouraged.
- Shall be deployed and struck at a minimum of 50 times without loss of functionality of component failure
- It is desired that the system perform fully in extreme environmental conditions from -60F to 120F
- Shall have an estimated production price of $150,000 or less.
- Shall be compatible for use with military vehicles. The following vehicles are listed as examples: M939 5 Ton Truck, Army Medium Tactical Vehicle Truck (MTV), and the Heavy Expanded Mobility Tactical Truck (HEMTT)
- Shall withstand a roof load of 40 psf.
- Desired: provide environmental control to the inhabitants of the shelter
- Desired: provide on board power generation
- Desired: capability to complex to other VMECoP or Army tent systems.

PHASE I: The Phase I awardee shall develop/prototype a VMECoP design addressing the aforementioned requirements.

The awardee shall report monthly on their progress, in the form of a technical report indicating accomplishments, technical drawings, project progress against proposed schedule (manage to budget), tables, graphics, and any other associated test data.

Deliverables:
- Six monthly reports, with each report containing the following:
  - o Technical progress to date, against proposed requirements and schedule.
  - o Technical achievement highlights, as well as problems or decision-points reached.
  - o Draft of Interoperability analysis for VMECoP transport
  - o Draft of analysis and visualization of the VMECoP expansion and striking sequence. The analysis of expansion and striking sequence should include a discussion of recommended safety features and potential safety hazards.
  - o Draft of recommended testing to include at a minimum: dimensional, environmental, and transportation.
  - o Expenditure to date, against proposed schedule.
  - o Within first two reports, present market research of all existing and future expandable shelters and their applicability to a military deployment.
- Final Technical Report suitable for publishing on to the Defense Technical Information Center (unclassified) that describes the project, the work performed and recommendations.
- A Final Concept Package shall be submitted containing the following:
  - o A system model. The system model should be a small scale model, physical or virtual, that would convey confidence in the system would meet deployment and set up times listed in the objective and description sections.
  - o Analysis and visualization of the shelter's expansion and collapse while both vehicle mounted and emplaced on the ground. The analysis of expansion and striking sequence should include a discussion of recommended safety features and potential safety hazards.
  - o Demonstration of the erect/strike capabilities of the system demonstrator model
  - o Finite Element Model demonstrating structural integrity of proposed design and structural capability to withstand deployment/strike loads of 50 cycles.
  - o Small samples of materials representing the floors, walls, and structural/mechanical components of the shelter shall be provided that would demonstrate confidence that the system would meet the required characteristics and properties listed.

- o Concept level technical drawings, showing the shelter expanded and collapsed.
- o High resolution graphics of the proposed concept.
- o A concept for interfacing with power generation, power distribution assets, and ECU equipment.
- o Interoperability analysis for transport, loading, unloading.
- o Analysis and visualization of the shelter's expansion and collapse. The analysis of expansion and striking sequence should include a discussion of recommended safety features and potential safety hazards.
- o The proposer shall construct a list of recommended testing to include at a minimum: dimensional, environmental, and transportation. Transportation testing should include appropriate tests for movement via rail, ground, internal and external air, and transport via common MHE. At a minimum this list of tests should include:
  - • ISO compliance testing,
  - • Convention for Safe Container (CSC)
  - • Environmental Testing
  - • Road Transportation testing
- o A cost analysis of the systems life cycle, including the cost of maintenance items and consumables, as well as the initial capital cost of procuring the system – over 5 years.

PHASE II: Phase II is a significant R&D effort resulting in a fully functional, full scale VMECoP prototype. Additionally, the prototype developed shall at a minimum meet the threshold requirements listed in the Description section of this document. The Phase II effort will focus on prototype development, validation of function and demonstration.

Required Phase II tasks and deliverables will include:
- • "Monthly" and "Final" reporting, as detailed in Phase I, to cover the 24 month Phase II "Period of Performance".
- • Deliver technical drawings of VMECoP.
- • Deliver editable 2-D CAD files or 3-D model of the VMECoP, Solidworks format desired
- • Deliver high resolution graphics of the final prototype.
- • Deliver user manual for the prototype.
- • Modifications and improvements to FEA models developed in Phase I to represent the full scale, final design, including analysis of erect/strike loading.
- • Devise maintenance plan, and indicate all supplies needed, including cost, quantity, and frequency of replacement thereof.
- • Transportation testing reports, required transportation testing per agreed upon list produced as part of Phase I.
- • Deliver a complete VMECoP prototype exhibiting the desirable performance characteristics listed in the description section above. Delivery should be to Base Camp Integration Lab, Fort Devens, MA or mutually agreed upon alternative venue.
  - o Demonstrate each of the performance characteristics of the VMECoP as listed in the description section above.
- • Demonstrate interoperability with a vehicle.
  - o Vendor to provide a commercial flatbed vehicle for demonstration purposes.
  - o In addition to a commercial flatbed vehicle, the Government may provide a military vehicle for demonstration purposes, pending availability of such vehicle. The following vehicles are listed as examples: M939 5 Ton Truck, Army Medium Tactical Vehicle Truck (MTV), and the Heavy Expanded Mobility Tactical Truck (HEMTT).

- • An updated cost analysis of the systems life cycle, including the cost of maintenance items and consumables, as well as the initial capital cost of procuring the system – over 5 years.
- • A final report suitable for publishing onto the Defense Technical Information Center (unclassified) that describes the project and the work performed. An addendum shall also be provided which provides full detail and test results of the system developed, the system performance and the method by which the performance characteristics in the Description section were achieved.

PHASE III DUAL USE APPLICATIONS: The initial use of this technology is for highly mobile military tactical capabilities, but we foresee an extension of the technology to other governmental organizations and commercial industry. For example, the following areas have been identified as commercial markets requiring improvements in

the mobility of tactical shelters:
- Mobile environmentally controlled space, required for:
  - o humanitarian medical efforts,
  - o disaster response,
  - o And commercial construction applications.

The potential for Dual Use applications of the Dynamic Expandable VMECop, would grow rapidly once power generation and HVAC assets are integrated into the structure itself.

REFERENCES:
1. Department of Defense Standard Family of Tactical Shelters (Rigid/Soft/Hybrid), Joint Committee On Tactical Shelters (JOCOTAS), 2011 Jan, Accessed on 20 May 2019 https://apps.dtic.mil/dtic/tr/fulltext/u2/a568854.pdf

2. Test Operations Procedure (TOP) 10-2-175 Tents and Shelters, UA Army Aberdeen Test Center; http://www.dtic.mil/dtic/tr/fulltext/u2/a548259.pdf

3. ISO 1496-1, Series 1 Freight Containers, ISO; https://law.resource.org/pub/us/cfr/ibr/004/iso.1496-1.1990.pdf

4. ISO 668, ISO Standard Freight Containers; https://en.wikipedia.org/wiki/ISO_668

5. TECHNICAL MANUAL, OPERATOR, ORGANIZATIONAL, DIRECT SUPPORT, AND GENERAL MAINTENANCE FOR SHELTER, TACTICAL, EXPANDABLE, ONE-SIDED; https://liw.logsa.army.mil/etmapp/api/general/search/059982/0/pdf

6. PERFORMANCE SPECIFICATION TENT, EXTENDABLE, MODULAR, WARFIGHTER (TEMPER) –MIL-PRF-44271B; ttp://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-44271B_37037/

7. Technology Readiness Assessment; http://www.acq.osd.mil/chieftechnologist/publications/docs/TRA2011.pdf

8. DEPARTMENT OF DEFENSE TEST METHOD STANDARD ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS - MIL-STD-810G, Oct 2008; http://www.atec.army.mil/publications/Mil-Std-810G/Mil-Std-810G.pdf

9. DEPARTMENT OF DEFENSE DESIGN INTERFACE STANDARD FOR TRANSPORATION CRITERIA - MIL-STD-1366E, Oct 2006; https://www.sddc.army.mil/sites/TEA/Functions/Deployability/TransportabilityEngineering/Transportability%20Engineering%20Publications/MIL-STD-1366E.pdf

10. DEPARTMENT OF DEFENSE DESIGN CRITERIA STANDARD HUMAN ENGINEERING- MIL-STD-1472G, January 2019;http://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=36903

KEYWORDS: Command Post, Shelter, Expandable, ISO, Vehicle, Tactical, Mobile

A20-067 TITLE: Advanced Materials for Power Electronics

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: The Army is interested in improving its power electronics systems for aviation. Industry is currently taking advantage of breakthroughs in Silicon Carbide (SiC) and Galium Nitride (GaN) power electronic systems that can produce considerable efficiency gains. The Army would like to explore ways to utilize these systems on current rotorcraft platforms and Future Vertical Lift (FVL).

DESCRIPTION: Current legacy power electronic equipment are inefficient in comparison to modern equipment. By taking advantage of newer technologies, the Army hopes to reduce the size and weight of these systems while providing more capability to the warfighter.

The SBIR is intended to explore opportunities for the Army to utilize emerging technologies to improve electrical distribution. Systems such as the Regulated Transformer-Rectifier Unit (RTRU), which typically have an efficiency of 70~80% is a prime example of where gains can be made.

Classified proposals are not accepted under the DoD SBIR Program. In the event DoD Components identify topics that will involve classified work in Phase II, companies invited to submit a proposal must have or be able to obtain the proper facility and personnel clearances in order to perform Phase II work.

PHASE I: Under phase I, the electrical system in Army Rotorcraft should be researched and trades analyzed to determine what benefits could be realized by the Army. The Army would like to have an understanding of trade spaces and areas of improvement that can be realized for power electronics on aircraft.

The Army currently utilizes systems within the following specifications:
AC Generators: 40KVA-60KVA, 115VAC, 400Hz, at ~85% efficiency (min)
RTRU: 28VDC output @ 250-400A ~85% efficiency (min)

The Army desires to explore systems with the following specs:
AC Generators: 45-70KVA, 115-270VAC, 400Hz, at 95+% efficiency
RTRU: 28-270VDC @ +400A +95% efficiencies

Note: If a DC voltage bus is utilized the Army will also need a way to supply 28VDC to its legacy systems.

Current systems also have a MIL-STD-810G environmental requirement.

A report should be delivered to the Army with documenting the design decisions the Army could make when utilizing a more advanced system. If possible, a demo would be desired.

PHASE II: Under phase II, the Army would desire working prototypes with actual simulated aircraft electrical loads. A laboratory environment would need to be setup that would simulate the aircraft loads. Additionally, this phase should include qualification testing to ensure ability to comply with Army requirements. The Army would like testing conducted to show the optimal setup that would be required for facilitate Army rotorcraft power needs.

The final deliverable would be a report with testing and design data that would give the Army a path forward to utilize modern power electronics equipment.

PHASE III DUAL USE APPLICATIONS: Under phase III, the Army desires to pursue full qualification of the components and aircraft integration/testing on UH-60, AH-64, CH-47, and/or FVL. Additionally it is envisioned that this technology will have applicability to the commercial aircraft market.

The final deliverable for this effort would be a qualified modern, integrated power electronics.

REFERENCES:
1. MIL-STD-810G

2. MIL-STD-704

3. RTCA/DO160

4. MIL-STD-461

KEYWORDS: Generator, Regulated Transformer-Rectifier Unit (RTRU), Power Electronics, Power Distribution, Power

A20-068 TITLE: Additive Manufacturing (AM) for Aviation Shop Sets

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Increase and Enhance Fleet Readiness of Army Aviation plus Reduction in non-mission capable (NMC) time.

DESCRIPTION: The Army Program Executive Office, Aviation; Product Director, Aviation Ground Support Equipment (AGSE) is interested in innovative technologies to include in the Aviation Shop Sets. The Aviation Shop Sets provide approximately 3000 tools housed in ISO S/783G and S/784G one-sided expandable tactical shelters. These shelters also include cabinets, work tables and large metal working equipment to maintain Army aircraft and are deployed around the world. The Aviation Shop Sets also provide field maintenance support and test and measurement equipment that are not included in aviation maintenance personnel's individually assigned tool kits. Proposed AM systems are expected to significantly improve aircraft readiness levels through the ability to manufacture tools, support equipment, and aviation grade spare parts. This capability would enable units to continue with the mission when the procurement system is not responsive. This will also add the capability for on-site repair of existing tools, equipment, and aircraft reducing the reliance on a delayed procurement system especially in remote locations. The proposed system would have the capability to reproduce or repair most hand tools in the Aviation Shop Sets with similar or same material and quality. This would enable maintainers to always have the tool needed at the time needed resulting in improved readiness levels. The proposed AM system would also be a component of the Aviation Shop Set. Proposed AM systems should also be mindful of future requirements surrounding the Improved Turbine Engine and Future Vertical Lift (FVL) platforms. Developmental and Operational Testing of the proposed AM solution will be required to substantiate performance to determine if the system as a whole meets the Army's requirements and is capable of fielding a first unit within 24 months.

PHASE I: AGSE would like to examine the feasibility and extent of AM devices' capability to replicate, replace, and repair tooling and parts used to maintain Army Aviation assets. Identify potential uses and capability gaps that can improve or leverage Army Aviation readiness using AM technologies within Army aviation maintenance in both garrison and deployed environments. Identify and characterize the advantages and benefits of utilizing AM technologies to include areas such as, but not limited to: cost, technical, training, readiness, logistics, technology limitations, and weight. The AM capability studied will need to meet necessary size and weight criteria to enable packaging within the current footprint of the Aviation Shop Set. Additionally, the AM capability must duplicate the necessary strength, ruggedness, and application to complete the tasks of maintaining Army Aviation assets.

PHASE II: AGSE would like to leverage the feasibility determination accomplished in Phase I. Objectives of Phase II are to: A) Procure up to 3 AM devices for demonstration/testing, B) Demonstrate AM capability to produce multiple tools and/or parts required for Army aviation maintenance, C) Demonstrate the ability for the prototype AM device to fit within the Aviation Shop Set, D) Demonstrate the ability for the AM device to duplicate tools or parts similar in physical characteristics such as strength, ruggedness, and application, E) Complete a Technology Readiness Assessment and provide a document detailing the artifacts and justification to satisfy TRL determination. The offeror will demonstrate a capability of completing the widest array of manufacture/repair of tooling necessary to render the Aviation Shop Sets and associated equipment fully mission capable.

PHASE III DUAL USE APPLICATIONS: AGSE will POM for funding necessary to procure and retrofit Aviation Shop Sets with at least one selected AM device. Entry into Milestone B of the Acquisition development life-cycle including the completion of all life-cycle targets including development of a training plan for TRADOC, necessary user testing, and sustainment strategies to support the enabling of this capability. AGSE will be charged with the complete life-cycle management of the Aviation Shop Set.

REFERENCES:
1. Direct Measurement of Energy in Additive Manufacturing (AM) Paper by Federico Sciammarella, Northern Illinois University, sciammarella@niu.edu.

2. Additive Manufacturing (AM) for Complex Maintenance Tooling and Training Systems Paper by Bryce Weber, NUWC Keyport, Bryce.a.weber1@navy.mil.

3D Metal Printing for the Factory Floor Paper by Tom McDonald, Optomec, INC. tmcdonald@optomec.com.

4. Additive Manufacturing Handbook: Product Development for the Defense Industry, 2017, edited by Adedeji B. Badiru, Vhance V, Valencia, David Liu, ISBN-13: 978-1-4822-6408-1.

5. Advances in 3D Printing and Additive Manufacturing Technologies, 2017, edited by David Ian Wimpenny, Pulak M. Pandey, L. Jyothish Kumar, ISBN 978-981-10-0811-5.

6. Additive Manufacturing Materials, Processes, Quantifications and Applications, 2018, edited by Jing Zhang, Yeon-Gil Jung ISBN: 978-0-12-812155-9.

7. Additive Manufacturing, 2019, edited by Rupinder Singh, J. Paulo Davim, ISBN-13: 978-1-1380-5060-0.

KEYWORDS: Additive Manufacturing, Rapid Fabrication, Aviation, Readiness, 3D Printer, 3D Scanner, Laser Engineered Net-Shaping, Selective Laser Sintering, Multi-Jet Modeling

A20-069 TITLE: Phased Array SATCOM System for Group 2 UAS (Tactical BLOS)

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate a Phased Array SATCOM System for Group 2 UAS and Dismounts.

DESCRIPTION: The Army's FTUAS program is bringing rapid innovation and new capabilities to the US Army's combat brigades. The FTUAS program is reducing the size of drones at the same time as bringing increased capabilities. An increasingly difficult problem is the ability to stay connected to the network while conducting missions that last 8 hours or more. System agile satellite communications (the ability to use GEO, MEO, or LEO systems) will greatly enhance the military utility of the Army's FTUAS. The Phased Array technology must be cost effective in order to equip the FTUAS in quantity and must be compatible with the next generation tactical terminals. The system should be capable of supporting multi-megabit per second connections to different satellite system in different types of orbit. The system should have the ability to do make before break to ensure no dropouts when transitioning from one satellite to another. This capability when complete will support added resiliency for Army and Multi-Domain Battle (MDB) mission threads in a contested environment. Once complete, this capability could be scaled for use in other Army systems.

In addition to the DoD environment, this proposal has potential for commercialization. As we move towards an "Internet of Things" approach where IP addressing is frequently used and wireless technology is used to send system status or update information, this could provide a much needed, smaller form factor satellite connection. Another potential commercial application would be in the proliferating unmanned vehicle market in the commercial sector.

PHASE I: Identify the key component technologies required to support the performance and cost goals for the phased array system. Model the system to show how RF performance will be achieved within the Size Weight and Power (SWAP) constraints of FTUAS. The weight should be less than 8lbs and the power should be less than 200 watts. The size should be compatible with future FTUAS platforms. The analysis should show basic performance parameters associated with SATCOM links to include at a minimum frequency bands supported, EIRP and G/T. The initial analysis should demonstrate the cost to produce the system within the FTUAS SWAP constraints and the feasibility of meeting requirements in Mil-Std-188-164B.

PHASE II: Design and develop a system agile phased array satellite communications prototype unit to show the feasibility of providing SATCOM for FTUAS. Test and demonstrate key technologies to support an initial capability and identify areas requiring additional research and development to support the SWAP constrained capability. Demonstrate as many performance parameters as feasible and identify growth path to full performance with the FTUAS swap. Identify key risk areas where performance, SWAP coupled with minimum performance of real time video over SATCOM is the primary concern.

PHASE III DUAL USE APPLICATIONS: Deliver working units to the FTUAS program for integration and test. Obtain Defense Information Systems Agency (DISA) certification to work on military satellite systems. Obtain commercial certification for use on commercial satellite networks. This will pave the way for use on commercial satellite communications systems.

REFERENCES:
1. DISA (https://www.disa.mil/)

2. MIL-STD-188-164b

3. MIL-STD-188-165b

4. FedBizOpps.Gov: Future Tactical Unmanned Aerial System (FTUAS), https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=df9e464c23db523fa4658763460ab954

KEYWORDS: Satellite Communications (SATCOM), Unmanned Aircraft Systems (UAS), Geosynchronous Orbit, Medium Earth Orbit, Low Earth Orbit

A20-070 TITLE: Cross Domain Processing Solution (CDPS) for Group 2 UAS

TECHNOLOGY AREA(S): Information Systems

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

OBJECTIVE: Develop and demonstrate a Cross Domain Processing Solution (CDPS) for Group 2 UAS and Dismounts.

DESCRIPTION: The Army’s FTUAS program is bringing rapid innovation and new capabilities to the US Army’s combat brigades. The FTUAS program is reducing the size of drones at the same time as bringing increased capabilities. The evolution of small form factor SIGINT, EWW, and mini EO/IR with lasing payloads will greatly enhance the military utility of the Army’s FTUAS. To provide an advanced exploitation and dissemination experience to both external uses and the FTUAS operations, onboard data processing at varying simultaneous security classification levels is required. The Cross Domain Processing Solution (CDPS) must offer power efficiency and compact size to fly on a Group 2 UAS. The solution shall manage processing of (2) or more domains simultaneously. The CDPS shall process and provide operators in the FTUAS ground control station with relevant data applicable to their security classification and mission needs. This solution also needs to implement a framework for date and time accuracy where GPS may not be available for extended durations. This capability, when complete, will support increased interoperability for Advanced Teaming mission threads.

In addition to the DoD environment, this proposal has potential for commercialization. The technology could be leveraged in mainstream IT to provide physical separation between sites and networks. Another potential commercial application would be in the delivery of data by commercial unmanned vehicles to multiple, distinct customers during flight.

PHASE I: Identify the key component technologies required to support the performance, size, and cost goals for the CDPS. Model the system to show what processing performance (CPU and graphics) will be achieved within the Size Weight and Power (SWAP) constraints of FTUAS. The weight should be less than 5lbs and the power should be less than 100 watts. The initial analysis should demonstrate the cost to produce the system within the FTUAS SWAP constraints and the path ahead for receiving certification from the NSA for multiple domain processing.

PHASE II: Design and develop a hardware prototype unit to show the feasibility of processing data and providing date, time information for FTUAS in the constrained SWAP environment. Test and demonstrate key technologies to support an initial capability and identify areas requiring additional research. Demonstrate as many performance parameters as feasible and identify growth path to full performance with the FTUAS swap. Identify key risk areas where performance due to SWAP is a concern. Validate plan for NSA certification.

PHASE III DUAL USE APPLICATIONS: Deliver working units to the FTUAS program for integration and test. Obtain NSA certification to operate on designated networks. Obtain commercial certification for distribution to multiple, distinct customers.

REFERENCES:
1. NIST Special Publications 800 Series

2. FedBizOpps.Gov: Future Tactical Unmanned Aerial System (FTUAS), https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=df9e464c23db523fa4658763460ab954

3. Cross Domain Enterprise Service Site, https://public.cyber.mil/cdes/

KEYWORDS: CDS, Unmanned Aircraft Systems, GPS, EWW, EO/IR, SIGINT, NSA

A20-071 TITLE: Radio Network Sniffer and Baseband Signal Analysis Tool

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: OBJECTIVE: Design and develop a tool that provides Radio Frequency (RF) digital channel emulation, captures I/Q samples in real-time, processes and analyzes these baseband signals across all radios in the network to evaluate radio network performance. The tool will enable evaluation of performance metrics such as network connectivity, bandwidth efficiency, reaction time to changes, performance in intermittent conditions, scalability, susceptibility to interception and detection, etc. This capability will allow advance evaluation of GOTS and COTS waveforms necessary to understand their suitability in ever challenging tactical use cases spanning from increased capacity for data transport, to real-time control of unmanned objects and vehicles, and ability to operate in congested and contested environments, which is not currently possible through spectrum analyzers.

DESCRIPTION: DESCRIPTION: Evaluating large ad hoc network solutions in tactically relevant scenarios poses unique challenges that are not adequately addressed in the current state of the art wireless network evaluation. This is particularly true in the context of integrated, network-centric communications in a congested and contested radio frequency (RF) environment. The current state of the art channel emulators provide ability for the radios to communicate in realistic environment, which allows the system evaluators to measure the application layer performance in different channel conditions. This performance measurement ability is essential but it does not provide the necessary insight into the RF characteristics of the radios in different network scenarios. This level of advance baseband analysis capability across radio networks is not available through spectrum analyzers. Additionally, Army does not have a tool to compare different radio network solutions as far as RF level signaling is concerned. This lack of visibility could hide vulnerabilities of a radio system. For example, two radio solutions that have similar network performance may have drastically different RF footprint, which makes one solution more susceptible to RF interception and detection. The ability to capture and analyze RF data from a network of connected radios will help in understanding such behaviors.

A comprehensive analysis of a radio system requires analysis across all communication layers. The information available through network management entities is useful but rarely provide deep insight into the radio behavior. The ability to capture and analyze data across application, network and RF layers is necessary to provide a comprehensive assessment of radio performance. A tool that can measure RF behavior as well as network behavior will help the Army to better understand and evaluate various radio technologies. It will help detect any system vulnerability in early stages of adoption, and ultimately reduce the cost of developing new technologies relevant to the Army.

To fill this gap Army is soliciting the development of a radio network evaluation technology that provides visibility into the behavior of the radio network. The evaluation tool must provide Radio Frequency (RF) digital channel emulation, capturing of I/Q samples in real-time, and processing and analysis of baseband signals across all radios in the network to evaluate radio network performance. This tool should provide recording and playback of several minutes of Network and RF environment for advanced radio systems where the corresponding packets and RF emissions are tagged with the identity of the emitter. The recording must support at least 16 SISO radios as well as 4 4x4 MIMO radios. This tool must support channel bandwidth of at least 250 MHz. The tool must provide standard interface to external tools such as MATLAB and other like tools. This interface could be leveraged to consume more advanced channel effects generated by these external tools and for analysis and reporting. The network analysis tool must include MATLAB scripts for analysis and reporting.

PHASE I: Conduct a design study of the Radio Network Sniffer and Baseband Signal Analysis Tool. The design must cover Radio Frequency (RF) digital channel emulation, real-time capturing of I/Q samples, processing, analysis, and playback of baseband signals across all radios in the network. Design analysis must address accuracy, speed, and scalability of the approach. Demonstrate proof of concept technology for two radios.

PHASE II: Finalize the design of the Radio Network Sniffer and Baseband Signal Analysis Tool. Build and deliver evaluation tool that can support recording of Network and RF interactions between at least 16 SISO radios and 4 4x4 MIMO radios. This tool must support channel bandwidth of at least 250 MHz. The evaluation tool should include matlab interface and scripts to read and analyze the data. The ability to record RF channel with tagged meta-data should be demonstrated using tactical radios connected through an RF link emulator where the channel is drawn from the terrain data of a geographical area that will be defined by the Army. The evaluation tool should be able to emulate the RF recording at any point on the identified map. The tool should be delivered to Army for further testing and evaluation. Potential military and commercial applications will be identified and targeted for Phase III and commercialization.

PHASE III DUAL USE APPLICATIONS: PEO C3T / PM Tactical Radio / PM Tactical Networks will have high interest in the Radio Network Sniffer and Baseband Signal Analysis Tool as they will be looking to evaluate commercial radios and waveform technologies for Army's Integrated Tactical Network (ITN). The development of this tool will enable fast and effective way to evaluate and characterize new radio technologies. The tool will also benefit a wide variety of communications and sensor networks and vendors for both military and civilian applications.

REFERENCES:

1. ns-3: A discrete-event network simulator for Internet systems: https://www.nsnam.org/

2. The Extendable Mobile Ad-hoc Network Emulator (EMANE): NRL next-generation framework for real-time modeling of mobile network systems. https://www.nrl.navy.mil/itd/ncs/products/emane

3. New electronic simulation forum for wireless communication will host much of DARPA's Spectrum Collaboration Challenge. https://www.darpa.mil/news-events/2017-04-21

4. RFnest™: A network channel emulator that allows a full mesh of wireless nodes to experience realistic channels effects. https://www.i-a-i.com/product/rfnest/

5. Key Sight Technologies: N9040B UXA Signal Analyzer, Multi-touch, 2 Hz to 50 GHz. https://www.keysight.com/en/pdx-x202152-pn-N9040B

6. Advanced I/Q Signal Processing for Communication Systems: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.133.5905&rep=rep1&type=pdf

7. Tektronix: TTR500 Series Vector Network Analyzer (VNA): https://www.tek.com/vna/ttr500

8. JFW Industries: RF Matrix Switches: https://www.jfwindustries.com/product-category/test-systems/matrix-switches/

KEYWORDS: Channel emulation, RF Matrix, I/Q Signal Processing, Channel Effects, Spectrum Analyzer, MANET, RF footprint, Radio network evaluation, MIMO radios, Waveforms

A20-072 TITLE: Machine Learning Waveform Agnostic Electronic Warfare Countermeasures for Army Tactical Radios

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: The objective of this research will be to develop and demonstrate countermeasures to electronic warfare (EW) attacks on communication's systems thereby producing communications systems that have increased

EW resilience.

DESCRIPTION: Historically, US Army tactical radios use hard-coded TRANSEC techniques to counter specific simple EW threats against very specific communications waveforms. With the advent of Software Defined Radios new electronic attack (EA) techniques are increasing in sophistication and being developed and deployed at a rate outpacing waveform development. Artificial Intelligence (AI), and especially Machine Learning techniques, have been demonstrated as applied research (TRL 3-5), that can learn performance of friendly communications waveforms over time, recognize anomalies in behavior, and adapt to overcome EW threats.
The US Air Force and Navy have found some success in employing AI against Radar threats. Largely land bases, the US Army is primarily concerned with communications threats, yet much of the same AI might apply for both RADAR and comms.

PHASE I: The Phase I effort should demonstrate, in a laboratory environment, the ability of the AI algorithms to, based on performance observed over time, learn to recognize when SINCGARS, MUOS, and/or TSM waveforms are experiencing an EW attack (brought on by skilled EA operators using sophisticated modern attack techniques) and respond within five minutes to adapt and counter the attack without a-priori information regarding the nature of the attack.

PHASE II: Following the precedent of previous Product Manager Electronic Warfare Integration (PdM EWI) Radio Interference Mitigation (RIM) efforts, the Phase II effort should demonstrate (TRL-6/7), within a relevant environment (e.g., Yuma, EPG, etc.) embodiment of this AI solution in a form factor with a clear path to a fieldable tactical solutions that runs independent to any particular radio acquisition effort.

PHASE III DUAL USE APPLICATIONS: Phase III should advance the technology maturity to embodiment of this AI solution in a form factor demonstrated an operational environment at operational vehicle speeds and at operational range separations with anticipated range of red EA systems. Commercial applications include robust resilient communications for private security industry, air traffic control, first responders counter terrorism EA against private sector targets. May also likely counter non-malevolent interference events in congested RF environments.

REFERENCES:
1. Waveform Agnostic Communications via Deep Learning, DeepSig, https://oshearesearch.com/, Tim OShea

2. DARPA Behavioral Learning for Adaptive Electronic Warfare (BLADE) Program, https://www.darpa.mil/program/behavioral-learning-for-adaptive-electronic-warfare

3. DARPA Adaptive Radar Countermeasures (ARC)

4. (DARPA) for the Network Universal Persistence (Network UP) project. https://www.militaryaerospace.com/computers/article/16726529/darpa-seeks-to-ensure-radio-communications-and-networking-reliability-in-jamming-and-interference

KEYWORDS: Electronic Warfare, EW, Resilient, Radio, Radio Frequency, Communications, Artificial Intelligence, AI, Waveform Agnostic, Antijam, AJ, Machine Learning, ML,

A20-073 TITLE: Every Camera a Biometric Checkpoint

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: The objective of this project is to develop/implement an artificial intelligence/machine learning (AI/ML) algorithm employed in video surveillance cameras to detect identities, track identities, and disseminate identities through facial recognition from live video surveillance cameras anywhere.

DESCRIPTION: The U.S. Army has a need to enhance security measures at Forward Operating Bases (FOBs) and other secured facilities by detecting threatening individuals, preventing infiltration by non-authorized personnel and rapidly authenticating authorized personnel. To meet this need PM DoD Biometrics is in need of advanced identity verification, biometric identification leveraging real-time video surveillance monitoring and exploitation technologies. The primary objective of the desired capability is to rapidly (in near real time) determine or verify a person's identity from live video surveillance by automatically detecting, tracking and submitting high-quality face images to a cloud-based enterprise face recognition and alerting system. The system will deliver this capability anywhere, anytime and using any digital video surveillance camera which has Internet/network connectivity. The US Army desires an AI/ML-based face detection, face tracking and face search submission edge-device(s) which is capable of monitoring live video surveillance feeds (from commodity video surveillance cameras to include embedded cameras on Android and iOS devices) coupled with an enterprise cloud-based watch list management and face recognition matching capability. This system is intended to standardize and centralize edge-device management/authorization, face matching, face match adjudication, authoritative watch list management, and alerting/notification mechanisms. The system must be scalable to biometrically enable a large array (10k+) of video surveillance cameras.

PHASE I: The objective is to develop an overall system design that includes specification of AI/ML based techniques employed, specification of architecture required to support concept of operation, sensor specifications required to achieve detect, track, match, and disseminate functions, recognition techniques employed by algorithm, and protocol for employment with current identity operations and intel platforms.

PHASE II: Develop and demonstrate a prototype system in a realistic environment. Conduct testing to prove feasibility over extended operating conditions.

PHASE III DUAL USE APPLICATIONS: Upon completion of research, software developed could be integrated into current biometric collection capabilities.

REFERENCES:
1. https://www.electronicshub.org/types-of-biometric-sensors/

2. https://www.cnet.com/how-to/facial-recognition-apple-amazon-google-and-the-race-for-your-face-facebook/

3. https://medium.com/@ageitgey/machine-learning-is-fun-part-4-modern-face-recognition-with-deep-learning-c3cffc121d78

4. https://www.quora.com/How-do-machine-learning-and-facial-recognition-algorithms-work

KEYWORDS: Machine Learning, Artificial Intelligence, Facial Recognition

A20-074 TITLE: Profile-to-Profile Face Recognition Matching Capability

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: The objective of this project is to develop/implement machine learning algorithms to automate identification of persons-of interest using face recognition with frontal and off-angle images from publically available information.

DESCRIPTION: While there has been much focus on the use of Artificial Intelligence (AI) or Machine Learning (ML) based techniques to automate identification of persons-of-interest using face recognition using frontal and off-angle face images, there is a need to develop/augment a face recognition algorithm to be capable of matching faces at extreme angles, such as faces captured as full 90-degree profile images. Many operational use cases exist whereby DoD is only able to collect a profile face image (for example, images extracted from Captured Enemy Material and from publicly available information) and has the need to identify the unknown subject. The Project Manager (PM) is interested in algorithms that incorporate state-of-art AI and ML processes. Approaches should address use of neural network design and training processes; use of performance and model monitoring tools; and data analytics for validation and visualization. Preference is for solutions to be agnostic to future systems to allow rapid capability increase for fielded systems – in particular the US Army's Video Identification, Collection and Exploitation (VICE) System.

PHASE I: The objective is to develop overall system design that includes specification of AI/ML based techniques employed, specification of architecture required to support concept of operation, sensor specifications required to achieve match by various distances, recognition techniques employed by algorithm, and protocol for employment with current identity operations and intel platforms.

PHASE II: Develop and demonstrate a prototype system in a realistic environment. Conduct testing to prove feasibility over extended operating conditions.

PHASE III DUAL USE APPLICATIONS: Upon completion of research, software developed could be integrated into the Near Real Time Identity Operations (NRTIO) or Next Generation Biometric Collection Capability (NXGBCC) systems architecture. Providing the match/no-match response through a cloud-based architecture supports the cueing of multiple sensors on and off the battlefield. Technology could also be used to support smart cities concept in support of local governments via friction payment authentication or law enforcement applications.

REFERENCES:

1. Alyea, L.A., Hoglund, D.E., Eds. Human Detection and Positive Identification: Methods and Technologies, SPIE. 1996.

2. https://www.cnet.com/how-to/facial-recognition-apple-amazon-google-and-the-race-for-your-face-facebook/

3. https://medium.com/@ageitgey/machine-learning-is-fun-part-4-modern-face-recognition-with-deep-learning-c3cffc121d78

4. https://www.quora.com/How-do-machine-learning-and-facial-recognition-algorithms-work

KEYWORDS: Machine Learning, Artificial Intelligence, Facial Recognition

A20-075 TITLE: Touchless Fingerprint Identification Toolkit (TFIT)

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: A software development kit (SDK) for mobile devices (iOS and Android) able to collect, process and match fingerprints from subjects (up-close and standoff) using stock rear camera. The SDK should provide (1) offline and online collection, processing and matching; (2) synchronization over disadvantaged, low-bandwidth connection when connected; and (3) online and offline matching against legacy (500 ppi), next-generation high-resolution (1000+ ppi) and minutiae-based fingerprints; and (4) advanced presentation attack detection (PAD) mechanisms. The SDK should support a wide range of import and export formats for interoperability with legacy and next-generation multi-biometric systems including support for probabilistic 1-to-many matches for partial latent collected prints from exploited sites. The SDK should be benchmarked for all conversions high resolution-to-legacy, legacy-to-high resolution and minutiae formats using NIST SP 500-305 and subsequent non-Appendix F matching methods. Finally, the SDK will pioneer a universal, open-source biometric envelope standard format to promote maximum interoperability and avoid future vendor-lock.

DESCRIPTION: Current mobile devices (phones & tablets) support specialized graphics processors and high resolution imaging cameras at low cost, but lack sophisticated biometric processing capabilities that would allow for efficient collection, processing and matching of fingerprint images at the edge. Future devices will get even more powerful in their capabilities but will lack software capabilities to exploit fingerprint image data unless software development kits (SDKs) are developed for watchlist 1-to-many matching in disconnected mode; fingerprints collected during operations; at-a-distance fingerprint image collection; backward-compatibility to legacy formats (ink and touch-based collected prints); and partial print processing and matching from site exploitation latent prints.

PHASE I: An operational, version 1.0 SDK and interoperability study to characterize the compatibility of high-resolution images with existing legacy ink & touch-based fingerprint databases based on NIST SP500-305 benchmark metrics (including PAD levels). Such an SDK will be released open source with plugin vendor drivers for biometric processing and matching engines but support version 1.0 of the interoperable biometric envelop format standard.

PHASE II: An operational, version 2.0 SDK with support for collection, processing and 1-to-many matching of latent fingerprints (including partial prints). The version 2.0 SDK will improve interoperability between legacy and next-generation (1000+ ppi and minutiae) formats, introduce new APIs for pluggable engines and re-benchmark matching (both 1-to-1 and 1-to-many) according to NIST SP 500-305 testing procedures (or subsequent NIST update editions).

PHASE III DUAL USE APPLICATIONS: A robust globally recognized fingerprint collection, processing and matching “backbone” (or “bus”) released as open source with pluggable extensions provided by vendors that provides interoperability between legacy and next-generation (1000+ ppi and minutiae) formats.

REFERENCES:
1. SOCOM 2019 Biometric TBE - https://www.nationaldefensemagazine.org/articles/2019/6/28/socom-seeks-smartphone-app-for-fingerprint-data

2. NIST Contactless Fingerprint Cooperative Research And Development Agreement (CRADA) - https://www.nist.gov/itl/iad/image-group/crada-program-contactless-fingerprint-capture-device-measurement

3. Bill and Melinda Gates Foundation - https://www.biometricupdate.com/201410/bill-gates-talks-biometric-identification-banking-for-emerging-countries

4. Bunq Bank - https://www.bunq.com/personal

KEYWORDS: biometrics, fingerprint, contactless, mobile, smartphone, standoff,

A20-076 TITLE: Correlating Threat with Identity

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: The objective of this project is to automate the detection and classification of vehicles and weapons from live video sources and correlate these objects with specific individuals using face recognition.

DESCRIPTION: To meet the vehicle/weapon detection and search requirements, PM DoD Biometrics plans to develop and integrate machine learning based vehicle and weapon detection algorithms within an open, scalable and flexible high-performance computing platform which collects, processes, analyzes and searches (by face and keyword) large photo and video collections and repositories. US Army’s Video Identification, Collection and Exploitation (VICE) System supports the rapid integration and operationalization of new computer vision algorithms which shall can detect and annotate objects of interest, such as vehicles, weapons, and other objects of military interest. The combination of face recognition and vehicle/weapon detection will enable operators and analysts to correlate persons-of-interest with objects-of-interest in support of Intelligence and Force Protection operations.

PHASE I: The objective is to develop an overall system design that includes specification of AI/ML based techniques employed, specification of architecture required to support concept of operation, sensor specifications required to achieve the ability to match identities associated with behavioral biometrics, and protocol for employment with current identity operations and intel platforms.

PHASE II: Develop and demonstrate a prototype system in a realistic environment. Conduct testing to prove feasibility over extended operating conditions.

PHASE III DUAL USE APPLICATIONS: Upon completion of research, software developed could be integrated into current biometric collection capabilities.

REFERENCES:
1. https://www.wired.com/2013/01/biometrics/

2. https://mexiaone.com/solutions/watchlist-person-of-interest-alerts/https://medium.com/@ageitgey/machine-learning-is-fun-part-4-modern-face-recognition-with-deep-learning-c3cffc121d78

3. https://www.quora.com/How-do-machine-learning-and-facial-recognition-algorithms-work

KEYWORDS: Machine Learning, Artificial Intelligence, Facial Recognition

A20-077 TITLE: Network Enclosure Architectural Concept Improvement

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Project Office Integrated Air & Missile Defense (IAMD) is the lead materiel developer of the Army's Integrated Air & Missile Defense (AIAMD) Integrated Battle Command System (IBCS). IBCS will fuse multiple Sensors into a Single Integrated Air Picture for Air & Missile Defense engagement planning and execution. One of the IAMD developed components is the Integrated Fire Control Network Relay (IFCN). A major component of the IFCN Relay is a Network Enclosure Assembly (NEA). The NEA houses many critical components to enable IAMD data. The NEA is plagued with multiple issues from size, weight, cooling capacity and access. The objective of this SBIR submission is to obtain innovative small business insights focused on Size, Weight, Power, and Cost (SWAP-C) improvements of the NEA architectural concept, improving the reliability and availability of internal components so that they work in the harsh environment and conditions experienced by the NEA, and improving maintainability of the NEA by providing Soldier access to perform operations and maintenance.

DESCRIPTION: The NEA, which is a proprietary item, possesses seven additional proprietary items as well as eight others of which one is ruggedized. Given the proprietary nature of the item and several of the components, the intent of this SBIR is to evaluate the NEA architectural concept as a whole by:
(1) Determine internal components that could be improved so that they operate in the harsh environment experienced by the NEA,
(2) Assess and reduce the cooling system requirements based on improvement of the NEA architectural concept.
(3) Enhancing maintenance and Soldier access to the NEA.

The components that comprise the NEA:
1. Integrated Fire Control Network Relay (IFCN) Mission Case (Proprietary) - Bare bone case with Environmental Control Unit (ECU), Quantity: 1
2. Environmental Control Unit (ECU) Controller Assembly (Proprietary) - ECU control logic, Quantity: 1
3. Power Distribution Unit (Proprietary) - Internal Power Distribution (DC Edge Attachment), Quantity: 1
4. Northrop Grumman (NG) Integrated Battle Command System (IBCS) High- Band Radio Frequency Unit (HRFU) control/status protector (Electromagnetic Interference (EMI) / Lightning protection) (Proprietary) - EMI/Lightning Protection, Quantity: 1
5. IBCS NG 100A 28 Volts Direct Current (VDC) Protector (Proprietary) - Circuit Breaker with EMI/Lightning Protection, Quantity: 1
6. Status & Coordinate Input Module (Proprietary) - Soldier input / display device to Initialization Global Positioning System Receiver Module (IGRM), Quantity: 1
7. Breaker Box, Electromagnetic Interference (EMI), 100 amp (A) (Proprietary) - Circuit Breaker with EMI/Lightning Protection, Quantity: 1
8. Initialization Global Positioning System (GPS) Receiver Module (IGRM) - The IGRM provides location information and 1 PPS signal to the HNR for initialization and continuous operation, Quantity: 1
9. PARVUS DURANET 18-Port Switch - Parvus Duranet 3000 Ethernet switch. The Parvus Duranet 3000 Ethernet switch routes classified data traffic between the Network Equipment and the PFPU, Quantity: 1
10. HAIPE, AltaSec KG250X, Ruggedized - HAIPE 3.0 encryption device (ViaSat AltaSec KG-250X). The KG-250X HAIPE 3.0 encryption device maintains the red / black communication boundary for all IFCN communication, Quantity: 1
11. Harris Baseband Processing Unit (BPU) - The BPU includes the control processor that hosts the HNW version 2 data link control layer, an OFDM burst modem that provides the HNW version 2 physical layer and an embedded mobile access switch router, Quantity: 1
12. Spectracom SecureSync Timing Unit Direct Current (DC) Power - The Spectracom SecureSync network timing unit provides critical system timing information, ensuring end-to-end synchronization with all IFCN nodes by means of a GPS-base NTP server, Quantity: 1
13. Telecommunication Systems (TCS) Tactical Router, MIL SPEC - Alt-Media Router, Quantity: 1
14. Media Converter Chassis - Fiber optic media converter chassis with Omnitron 119-0 media converters, Quantity: 1
15. NTN, Remote Global Positioning System (GPS) Antenna - GPS antenna, Quantity: 1

PHASE I: Investigate and research innovative technologies and architectures that can be incorporated into a new mission focused enclosure, component focused, which can improve reliability and availability, operate with less or without active cooling, and which can perform the same functions as the components listed in the NEA description. Once investigation and research of potential technology is complete, the offeror will, in an unclassified format, identify implementation options in a Phase I report.

Analysis information and prototypes developed during this phase must be supplied to the PEO Missiles and Space.

The Phase II effort will likely require secure access. The Phase I effort will not require access to classified information.

PHASE II: Using the technology and approach(es) identified in Phase I, design and package the improved components into mission focused prototype enclosures that are smaller, lighter, and more accessible. Analysis information and prototypes developed during this phase must be supplied to the PEO Missiles and Space.

Analysis information and prototypes developed during this phase must be supplied to the PEO Missiles and Space.

PHASE III DUAL USE APPLICATIONS: Transition the Phase II product into a deployable capability to enter into detailed technical and operational testing. Following testing, if successful, prepare sufficient data products to support potential procurement and fielding as part of the IAMD IBCS System as an integrated component.

REFERENCES:
1. Army Integrated Air and Missile Defense (IAMD), https://asc.army.mil/web/portfolio-item/ms-aiamd-2/

2. Army Integrated Air and Missile Defense (IAMD), https://www.msl.army.mil/Pages/IAMD/default.html

3. Office of Secretary of Defense (OSD) Director, Operational Test & Evaluation (DOTE) FY2016 IAMD Report, https://www.dote.osd.mil/pub/reports/FY2016/pdf/army/2016iamd.pdf

4. Detailed requirements will be provided upon successful acceptance of this proposal.

KEYWORDS: Army Integrated Air and Missile Defense (AIAMD), Integrated Air and Missile Defense (IAMD), Integrated Battle Command System (IBCS), Integrated Fire Control Network (IFCN), IFCN Relay, Network Enclosure Assembly (NEA)

A20-078 TITLE: Artificial Intelligence Application for Air and Missile Defense Combat Identification, Planning and Weapon Assignment

TECHNOLOGY AREA(S): Information Systems

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

OBJECTIVE: Project Office Integrated Air & Missile Defense (IAMD) is the lead materiel developer of the Army's Integrated Air & Missile Defense (AIAMD) Integrated Battle Command System (IBCS). IBCS will fuse multiple Sensors into a Single Integrated Air Picture for Air & Missile Defense engagement planning and execution. The objective of this SBIR submission is to develop a system architecture and algorithmic framework engine that supports artificial intelligence (AI)-based algorithms used to perform diverse functions such as Defense Design, Identification and Classification of tracks, Predictive Track Vectors, Sensor and Weapon Management, and other potential IAMD functions.

DESCRIPTION: Advances in artificial intelligence (AI) and deep learning techniques, in conjunction with rapid growth in GPU hardware performance have opened up new possibilities for exploitation of AI to perform highly complex tasks with performance exceeding that of more traditional approaches. Potential applications within the Army Integrated Air and Missile Defense (IAMD) system include Identification and Classification of tracked objects, Defense Design, and Dynamic Planning and Tasking.
To support AI / Deep Learning-based applications, the Army requires a robust, scalable architecture, framework and algorithm engine that can be utilized by multiple AI applications in an easily maintainable and extensible manner. The architecture and framework should include a combination of hardware and software that has a straightforward path of integration with current IAMD systems. The AI Engine should support integration and execution of multiple, simultaneous AI applications, as well as the ability to ingest, store, and process significant amounts of data.
In addition to execution, the architecture, framework and engine should support training of the algorithms, which minimizes hardware and software costs as well as permits on-the-fly enhancements to the different applications.

PHASE I: Develop a concept and initial prototype for a system architecture, framework, and algorithm engine. Demonstrate that the framework and engine will support AI-based functions such as Identification and Classification of tracks or others. Establish feasibility through evaluation of the framework via a study and/or use of simulation-based analysis.

The Phase II effort will likely require secure access. The Phase I effort will not require access to classified information.

PHASE II: Design, develop and deliver a prototype architecture, framework, and AI engine that demonstrates the capability to perform multiple AI-based functions, and is integrable with the current IAMD hardware and architecture. Perform the demonstration at a government defined facility. Prepare a Phase III development plan to transition the technology for the Army IAMD.

PHASE III DUAL USE APPLICATIONS: Transition the Phase II product into a deployable capability to enter into detailed technical and operational testing.

REFERENCES:
1. Vasudevan, Vijay. “TensorFlow: A system for Large-Scale Machine Learning.” Usenix Associate, USENIX OSDI 2016 Conference, 2 November 2016.

2. Vasudevan, Vijay. “TensorFlow: Large-Scale Machine Learning on Heterogeneous Distributed Systems.” Usenix Association, 2016. http://download.tensorflow.org/paper/whitepaper2015.pdf

3. Schmidhuber, Jurgen. “Deep Learning in Neural Networks: An Overview.” Neural Networks, Volume 61, January 2015, pp. 85-117. http://www.sciencedirect.com/science/article/pii/S0893608014002135

KEYWORDS: Artificial Intelligence, Deep Learning; Identification; Classification, Defense Design, and Dynamic Planning, automated resource assignment.

A20-079 TITLE: Improved Ground Based Fire Control Radar Interferometry Techniques

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Development fire control solutions for the C-RAM II PTS testbed radar and system development of prototype radar software to implement detection and tracking algorithms as well as ambiguity resolution algorithms, waveform improvements, processing capabilities.

DESCRIPTION: Radar systems providing high accuracy tracks are critical to the development of state-of-the-art solutions for the warfighter. These radar systems find utility as fire control radars associated with some interceptor and also as truth sensors for conducting flight tests with UAS, missiles, projectiles, interceptors, mortars, and more. The PEO Missiles and Space is interested in developing fire control solutions for the C-RAM II PTS testbed radar system. This effort requires the development of prototype radar software to implement detection and tracking algorithms as well as ambiguity resolution algorithms, waveform improvements, processing capabilities. There is also interest in enabling the radar to be integrated in a networked configuration to support command and control mission requirements. The aforementioned improvements also require that the radar can successfully be instrumented to collect data in contested Electronic Warfare and Cyber environments. Radar system and component level improvements and maintenance are expected in order to support demonstration events and prototype development.

It is the intent of this topic for the offeror to demonstrate the capability to create improved tracking techniques for the C-RAM II PTS testbed radar system. The proposals must result in software and/or hardware modifications to the system that enhance its performance and develop technologies that can be inserted to or assist fielded radar systems.

PHASE I: In Phase 1, the offeror shall research, develop and evaluate prototype algorithms for resolving angle ambiguities and improving the tracking performance of a C-RAM II PTS interferometric testbed radar. Additionally, as part of Phase 1, the offeror shall investigate and produce a concept for adding waveform agility to the testbed radar. The final product of Phase 1 shall be prototype algorithms for certain missions, algorithm documentation, and a report documenting the new waveform possibilities of the sensor. Algorithm prototypes are required during Phase I and must be supplied to PEO Missiles and Space.

PHASE II: In Phase II, the offeror shall use methods developed in Phase 1 to modify radar software for implementation of the algorithms presented in the algorithm documentation. The updated configuration shall be evaluated by the offeror via demonstration at a test range (location TBD) and against the targets for which the algorithms were developed. The purpose of this demonstration is to verify the improved radar performance. Additionally, the offeror shall develop a detailed software, firmware, and hardware design for adding transmit waveforms to the testbed radars signal generation capabilities. The modifications that are associated with adding waveforms to the library of the radar shall be described and established. The offeror shall calibrate the antennas of the testbed radar for optimal performance. These improvements to the waveform and antennas are aimed at improving the agility and tracking performance of the testbed. Furthermore, the offeror shall generate a concept and implementation path for a Hardware-In-the-Loop (HWIL) representation of the radar in order to conduct algorithm development testing and performance predictions. Finally, software development that enables the testbed to collect and process sensitive data is necessary and will require improvements to the source code and data recording process. The desired products of Phase II include: 1) software builds implementing algorithms and capability improvements, 2) Demonstration of the radar performance improvements, 3) Improved antenna array calibration, 4) A detailed prototype design concept for implementing additional waveforms capability, and 5) a prototype design to achieve an HWIL configuration. Analysis, documents, and prototypes are required during Phase II and must be supplied to PEO Missiles and Space.

PHASE III DUAL USE APPLICATIONS: For Phase III of this effort, the offeror shall expand upon the solutions of Phase II to develop an HWIL system for the radar and waveform transmit unit generating various waveforms. The purpose of the HWIL development is to create a prototype system for conducting radar performance predictions against different targets or interest using hardware and software components identical to those in the radar processor. The purpose of the waveform generation unit is to enable the development and testing of prototype search, acquisition, detection, and tracking algorithms on interferometric radar systems that result in improved radar capabilities. Prototypes are required during Phase III and must be supplied to PEO Missiles and Space.

Phase III applications: Particular military applications include generic radar sensor system applications for accurate tracking of specific targets of interest either as a truth sensor or fire control radar. Additionally, improved algorithms and testing capabilities enable pre-flight test predictions, improved radar accuracy performance, and engagement of more advanced targets. Transitions of opportunity include military grade radar systems utilizing interferometer techniques and phased array antenna apertures. The most likely path to transition the prototype algorithms and hardware is for a ground based radar program that will adapt the technology during their development and test cycle or for PEO Missiles & Space to utilize the testbed in an integrated air defense network as a testbed radar.

REFERENCES:
1. "Passive Direction Finding - A Phase Interferometry Direction Finding System for an Airborne Platform", Worcester Polytechnic Institute, October 10, 2012, Daniel Guerin, Shane Jackson, Jonathan Kelly, Submitted to: Project Advisors: Professor Edward A. Clancy, Professor George T. Heineman, Professor Germano Iannacchione, Project Supervisors: Lisa Basile, MIT Lincoln Laboratory, Kelly McPhail, MIT Lincoln Laboratory, Christopher Strus, MIT Lincoln Laboratory, https://pdfs.semanticscholar.org/66

2. "Comparison of Direction of Arrival (DOA) Estimation Techniques for Closely Spaced Targets", International Journal of Future Computer and Communication, Vol. 2, No. 6, December 2013, Nauman Anwar Baig and Mohammad Bilal Malik, http://www.ijfcc.org/papers/246-B243.pdf

3. Beamforming for Direction-of-Arrival (DOA) Estimation-A Survey, International Journal of Computer Applications (0975 – 8887), Volume 61– No.11, January 2013, V Krishnaveni, PhD. Associate Professor ECE Department PSG College of Technology, T Kesavamurthy, PhD. Assistant Professor (Sr.) ECE Department PSG College of Technology, Aparna.B PG Student ECE Department PSG College of Technology, https://pdfs.semanticscholar.org/55e2/3309292fd24c3e2839295b19e1b7a9d0540a.pdf

KEYWORDS: Interferometry, Phased Array Antennas, Algorithms, Waveforms, Signal Processing, Fire Control, Network

A20-080 TITLE: Continuous-Time Digital Signal Processing (DSP) Using Reconfigurable Devices

TECHNOLOGY AREA(S): Information Systems

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

OBJECTIVE: Modern missile systems require tremendous amounts of signal and information processing using constrained resources in an extreme environment. Multi-spectral sensors, high-bandwidth communications, and supersonic flight control demand significant processing power, while space and weight constraints limit available power and heat dissipation. It is uncertain that conventional Digital Signal Processing (DSP) approaches can provide the increased performance required in next generation missile systems. To meet this need, alternatives to conventional, power-hungry digital processing approaches are desired. A promising novel approach is continuous-time digital signal processing (CTDSP), which achieves similar or improved performance while offering a significant decrease in power and heat dissipation requirements [1]. In particular, continuous-time algorithms that can be implemented on reconfigurable hardware including field programmable gate arrays (FPGAs) can enable the flexible design of future missile systems. Because the power reduction of this technique is application-specific, an exact benefit to Army systems cannot be quantified at this time; however, power savings of as much as a factor of 3 have been reported [2]. This effort is designed to impact the Long Range Precision Fires and Air and Missile Defense Army Modernization Priorities.

DESCRIPTION: Continuous-time digital signal processing (CTDSP) offers a promising alternative to conventional digital signal processing (DSP) for systems constrained by size, weight, power and cost [3]. The defining attribute is the use of continuous digital states instead of discretely clocked samples. Gate outputs switch as input signals change, in contrast to conventional DSP where gate outputs update with a fixed frequency clock. As such, CTDSP can be described as unclocked digital processing. The primary potential benefit of CTDSP is a reduction in power consumption and heat generation due to reduced switching for low-activity signals. As CTDSP matures, the standard modules and functions that underlie many of the most common signal processing algorithms must be redesigned to operate using unclocked logic. Operations including linear filters, mixers, correlators, and even simple mathematical functions require a new design approach. Many key algorithms have been successfully demonstrated, primarily filters using FPGAs [3] and application specific integrated circuits (ASICs) [4]. Importantly, the development of conventional digital systems has been greatly aided by the widespread use of reconfigurable devices such as FPGAs. The inclusion of reconfigurable devices not only accelerates initial development but also facilitates maintenance and upgrade of fielded systems. To exploit recent advances, the development of continuous-time digital signal processing algorithms beyond linear filter networks that work on reconfigurable digital devices is highly desirable. These algorithms may use amplitude quantization of analog input signals but enable continuous, unclocked processing of the digital signals. Targeted algorithms will enable the common signal processing operations required for communications, sensing, and control that are typical of modern missile systems. Challenges include continuous-time digitizing of analog signal input, algorithm design, resource optimization, amplitude quantization effects, bandwidth limitations, and error correction or tolerance. Preferred designs will be vendor agnostic and portable across reconfigurable devices, with minimal tuning that is device dependent. The intent of this solicitation is to develop a suite of CTDSP algorithms to enable low-cost, low-power, reconfigurable signal-processing devices to support a large variety of applications. As such, the solicitation is not limited to a particular application or performance specification.

PHASE I: Conduct a design study to identify important signal processing blocks for implementation using continuous-time digital circuits on a reconfigurable device. These important processing blocks should, at a minimum, implement lowpass, highpass, bandpass, and notch filters as well as modulation. Simulation and theoretical analysis will identify a preferred concept design for signal representation and modularization of operations. Consideration will be given to analog signal interface, resource requirements, quantization effects, and portability within reconfigurable architectures.

PHASE II: Finalize an optimized suite of continuous-time signal processing tools implementable on reconfigurable gate arrays to support various signal processing requirements typical in a missile system. Performance metrics will establish improved performance compared to conventional DSP approaches in terms of size, power, heat dissipation, cost, and reconfigurability. Potential military and commercial applications will be identified and targeted for Phase III exploitation and commercialization.

PHASE III DUAL USE APPLICATIONS: The development of continuous-time digital signal processing to meet signal processing requirements using reconfigurable gate arrays enables a significant leap-ahead technology for signal processing to support communications, remote sensing, and control. These technologies offer potential benefits across a wide swath of communications and sensor networks for both military and civilian applications.

REFERENCES:

1. Y. Tsividis, “Continuous-time digital signal processing,” Electronics Letters 39(21), 1551 (2003).

2. Y. Tsividis, "Event-Driven Data Acquisition and Digital Signal Processing—A Tutorial", IEEE Transactions on Circuits and Systems—II: Express Briefs, Vol. 57, No. 8 (2010).

3. T. Beyrouthy, L. Fesquet, “An event-driven FIR filter: Design and implementation,” 22nd IEEE International Symposium on Rapid System Prototyping, 59 (2011).

4. C. Vezyrtzis, W. Jiang, S. M. Nowick, Y. Tsividis, “A flexible, event-driven digital filter with frequency response independent of input sample rate,” IEEE Journal of Solid-State Circuits 49(10), 2292 (2014).

KEYWORDS: Digital Signal Processing (DSP), Continuous-Time Digital Signal Processing (CTDSP), Field Programmable Gate Arrays (FPGAs)

A20-081 TITLE: Visor Projected Display NVG Camera

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Replace Generation III Night Vision Goggles with equivalent performance camera sensor to achieve wider field of view and integrate day and night HUD into visor projected helmet mounted display.

DESCRIPTION: Currently, the aviation heads up display (HUD) modifies the Generation III Night Vision Goggles to provide symbology overlay for aircraft instrumentation. This forces the Army to field two HUD displays, one for day use, another for night operation. The SBIR topic “Next Generation Aviation Helmet Mounted Display”, A18-089, is developing a low cost replacement for the current day display which offers a wider field of view to the pilots. This technology is incompatible with the fielded night vision goggles because the visor cannot be closed while wearing the NVGs. A digital night vision sensor is required for integration into the Visor Projected Helmet Mounted Display (VPHMD) such that a single display can be used in both day and night conditions. The night vision camera sensor must be equivalent to generation III NVG performance and operate on existing voltage and current available from the fielded HUD computer display power supply. The sensor shall not require cooling or active illumination to perform, and shall offer 60hz frame rate in high resolution. Weight is critical to head mounted avionics, so the total weight of the VPHMD cannot exceed the weight of the Generation III NVGs (590 grams) modified with the HUD display (additional 145 grams), and the moment arm of the replacement weight cannot exceed that of the existing fielded NVGs modified with the night HUD.

Camera companies around the world are working towards real time high definition ultra-low light sensors which may be capable of achieving equivalent operational performance to Generation III NVGs IAW MIL-PRF-A327945, paragraph 3.5.3.5, i.e., “The brightness gain (see 3.6.10) shall not be less than 5,500 fL per fL (footlamberts)”.

This solicitation intends to identify low level light sensor solutions that can be integrated with the VPHMD with the least amount of weight and power consumption, and verify the brightness gain equivalence to Generation III NVGs. This topic aligns with modernization priority for Soldier Lethality.

PHASE I: This effort shall identify an existing low level light sensor capable of being integrated into the VPHMD with minimal size, weight, and power consumption. A laboratory demonstration is required to demonstrate breadboard operation of the sensor and prove brightness gain equivalence to Generation III NVGs. A test report is required documenting the results of the laboratory demonstration and the brightness gain actually achieved by the sensor. The contractor shall write and deliver a plan for a Phase II integration of the sensor into the VPHMD. The integration plan shall project cost, size, weight, and power consumption of the sensor to be integrated into the VPHMD based on the breadboard build prototype.

PHASE II: The contractor shall partner with the day display vendor winner of SBIR topic "Next Generation Aviation Helmet Mounted Display", A18-089 to deliver a sensor solution which provides night video input to the VPHMD. A total of not less than eight sensors with all interface hardware shall be built and delivered. An interface control document shall be provided to the Government and the VPHMD vendor detailing mechanical and electrical interface to the VPHMD. The VPHMD vendor shall have project management control of weight/space/power assignment of the sensor integration.

The contractor shall host a Preliminary Design Review and perform a Critical Design Review (CDR) at the Government's facility in month eleven. Critical Design Review (CDR) shall serve as the first milestone at the end of year one. Both design reviews shall make projections for weight/space/power requirements of the sensor. CDR shall present a cost projection for the sensor. Design reviews shall address VPHMD top level requirements for environmental compliance (rain, dust, electromagnetic interference, etc.), automatic shutoff when exposed to bright light and rapid recovery when light is no longer on sensor, durability, and interface to VPHMD. Delivery of sensors to the VPHMD vendor for integration shall serve as the 2nd year milestone.

The contractor shall provide technical support to the VPHMD vendor by phone and travel to the VPHMD vendor site for first integration build activity. The contractor shall design the sensor as a replaceable module within the VPMHD by a soldier in the field using a standard Army electrical toolbox. The contractor shall provide final measured sensor capability and weight/space/power information to the VPHMD vendor so that the product specification for the VPHMD can be updated. The contractor shall perform a bench demonstration of the first sensor built to verify space/weight/power, functions, and capability.

Deliverables will include briefing slides for the design review, meeting minutes for bi-weekly status telecons and design reviews, a test plan for sensor performance demonstration showing compliance to VPHMD integration requirements, test report documenting test accomplishments, data for updated VPHMD performance specification reflecting measured sensor performance, and a report detailing projected cost of the final sensor design as a function of quantity from a minimum of 50 and up to 1000 at a time. A preliminary technical data package for the sensor module shall be delivered.

PHASE III DUAL USE APPLICATIONS: Develop production processes for sensor prototypes built and delivered in Phase II. Update the VPHMD item specification to reflect final production process weight and performance impact based on production configuration sensor. Build thirty six (36) production representative sensors to supply to VPHMD vendor for final operational testing on multiple US Army helicopter configurations. Provide technical data package for sensor module. Sensor may migrate into ground soldier night vision equipment. Primary commercial application of sensor will be replacement of expensive commercial night vision systems used for hunting, cameras for photography, police and firefighting applications.

REFERENCES:
1. SPI Infrared: https://www.x20.org/cmos-night-vision-sensor-hfis-x26/

2. SiOnyx: https://www.sionyx.com/resources/blogs/sionyx-night-vision-is-the-technology-to-beat/

3. Canon: https://www.usa.canon.com/internet/portal/us/home/products/details/cameras/cinema-eos/me20f-sh

KEYWORDS: HUD, Helmet Mounted Display, Night Vision

A20-082 TITLE: Docking Pouch for Soldier Electronic Devices

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Develop a pouch technology that serves as a docking station for personal electronic devices, connecting these devices into a body-worn electronics network.

DESCRIPTION: While home and office docking stations provide for quick pre-wired connection between a computer and local peripherals, those docking devices have not yet been adapted for wearable systems (Reference 1). Small batteries can charge individual devices, but must be paired directly to the device (Reference 2). Connectors for personal electronic devices are getting smaller, more robust, and are preparing for a booming market in wearable technology (References 3 and 4). The Army desires a pouch that can serve as a docking station for a personal electronic device and connect into a body-worn network. This pouch development effort will explore unique methods for combining electronics docking with textile systems.

When the personal electronics device is inserted, the pouch will guide the device to a connector and not allow incorrect insertion/connection. The pouch may require different configurations for the size of the device and the type of existing connector on the device. When mated, the device shall be connected to the power (5V minimum) and data network. Data transmission from the electronic device will use USB protocol compatible. Typical connectors on personal electronics will include variations of USB such as Type A/B/C, mini-USB, micro USB, and Lightning. Upon insertion of the device into the pouch, there shall be tactile feedback that the User senses to assure that a power connection is made.

The pouch connector shall vary as a function of the existing personal electronics devices. Examples of Personal Electronics Devices used in Army Aviation include (but are not limited to) Lightweight Wearable Environmental Control System (LWECS), 45 Watt battery, End User Device (EUD) (an Android cell-phone-sized device adopted from Nett Warrior by Air Warrior), and the Electronic Flight Bag (EFB) (a tablet-sized Android device).

The pouch shall provide protection from an aircraft environment to include sand and dust, Petroleum/Oil/Lubricants (POL), electrostatic accumulation, flash-fire, and rain. The pouch configuration may allow insertion of the device from the bottom so the connection is at the top of the pouch if it provides better protection from contamination. Other innovative approaches to avoiding sand and dust contamination are welcome. The pouch shall retain the personal electronics device and shall maintain connection between the pouch connector and the inserted device. The connection between the device and pouch shall not be broken during normal user motion to include walking, running, crawling, and jumping. The connection shall be rated to IP68 (International Protection Marking, IEC standard 60529).

While power and data requirements are driven by the particular device the pouch contains, the docking pouch will be used in an aircraft environment. Electromagnetic signal emission and susceptibility shall be compatible with Army rotary wing aircraft.

PHASE I: This effort shall be used to develop a strawman architecture and design for a docking pouch solution that integrates with a body-mounted power network. The offeror shall identify viable manufacturing technologies and techniques that can be used in the assembly and production of the docking pouch solution. Proposed solutions shall be robust for military applications. If weight savings can be achieved with an innovative attachment and carriage system for use with a tactical vest, the technology shall be presented in this phase. A trade study shall be presented which compares the potential technologies with relevant parameters, including performance measures, size, weight, reliability, cost, and manufacturability. From this trade study, the offeror shall provide a recommended path forward.

PHASE II: This effort shall be used to develop the docking pouch technical details and to produce a limited quantity of test articles. The offeror shall develop the details for the physical and electronic components, as well as the human performance features. The offerer shall develop an approach to verify that the objectives are achieved. Twelve sets of pouches (one battery, one EUD, one EFB, and one LWECS) shall be delivered. The offeror shall conduct a lab demonstration of the pouches and perform initial aircraft compatibility to include electromagnetic interference and electromagnetic compatibility tests. The offerer shall maintain communication with IPC-8941 Subcommittee developing Guidelines on Connections for E-Textiles (Reference 5). Communication from the subcommittee shall be used to ensure compliance with emerging standards. Lessons-learned from development shall be communicated back to the subcommittee for their consideration.

PHASE III DUAL USE APPLICATIONS: Military personnel will be able to quickly recharge mission equipment in their docking pouches, and well as automatically connect to wired and wireless aircrew information systems. Other potential benefits as a result of this effort include commercial applications such as safety and situational awareness gear for outdoor enthusiast market, mine safety, and off shore oil and gas consumer markets.

REFERENCES:

1. gofanco® Multiport Dock; https://www.gofanco.com/products/video-display/multi-port-dock.html

2. Go Puck Wearable Power; https://gopuck.com/

3. “Tough Connector Integrates Into Clothing;” Electronics Weekly, 11 June 2018; https://www.electronicsweekly.com/news/products/connectors/tough-connector-integrates-clothing-2018-06/

4. “Connectors Get Smaller, Tougher for Wearables;” Spencer Chin, Neoconix, 11 Feb 2016; https://neoconix.com/2016/02/11/connectors-get-smaller-tougher-for-wearables/

5. Institute of Printed Circuits (IPC) E-Textiles Initiative; http://www.ipc.org/ContentPage.aspx?pageid=IPC-E-Textiles-Initiative

KEYWORDS: e-textiles, electronic clothing, tactical vest pouches, smart fabrics, docking station, flame retardant fabric, connectors

A20-083 TITLE: Low-Latency, High-Bandwidth Expeditionary Mobile Data Networks for Supporting Future Live Training Simulation Capabilities

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop techniques and methodologies that reduce latency and increase scalability of mobile networks to support bandwidth requirements for future live training systems and simulations.

DESCRIPTION: Future live force-on-force training systems will require high-bandwidth, low-latency transfer of information to facilitate advanced simulation capabilities such as real-time direct & indirect fires, interaction with virtual entities (controlled by both live participants and constructive simulations), and streaming of virtual terrain data.

To limit the burden on participants and increase realism, live training systems are made as small as possible, limiting the on-board processing capabilities of these systems. For this reason, cloud-based computing is an attractive option for enabling the capabilities described above. However, cloud computing requires a high-bandwidth, low-latency network to ensure that data is exchanged between the cloud and the point of need quickly enough to accurately simulate real-world military operations.

The problem is further compounded by the expeditionary nature of Army live training, which often takes place in areas with little or no wireless data network infrastructure.

The Army is interested in exploring techniques and methodologies for enabling low-latency, high-bandwidth expeditionary mobile data networks to support future live training simulation capabilities.

PHASE I: Desired end product of Phase I is a whitepaper describing the design of the new network technologies along with quantified estimates on bandwidth and latency.

PHASE II: Desired end product of Phase II is a demonstration of new network technologies on a virtual or live network, along with metrics on bandwidth and latency. In addition, the offeror would provide a document describing the expected risks, costs, and performance of the networking technologies developed when deployed on a large (Combat Training Center-sized) network.

PHASE III DUAL USE APPLICATIONS: Desired end state of the Phase III would be a tech demo of new TRL 6 networking technologies in a live Army training network at a homestation training application.

REFERENCES:
1. STE Live OTA - https://trainingaccelerator.org/2019/06/ste-live-force-on-force/

2. STE Overview - https://www.youtube.com/watch?v=zzEXBPGKsgY

3. An intelligent route computation approach based on real time deep learning strategy for software defined systems", IEEE. Authors: Bomin Mao, Fengxiao Tang

KEYWORDS: Data Networks, Cloud Computing, Simulation, Cross-Domain Training

A20-084 TITLE: Cyber Training Big Data Analytics and Visualizations

TECHNOLOGY AREA(S): Information Systems

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

OBJECTIVE: Develop an innovative technical application of big data analytics and visualizations for cyberspace operations training environments and datasets that support virtualized compute, network, storage nodes, high fidelity synthetic internet/grey space traffic, specialized hardware-in-the-loop assets, and threat actor signatures/emulation. The capability would support the ability to collect, correlate, extract, visualize and assess Cyber Mission Forces (CMF) embedded within high fidelity training environments across defensive/offensive operations and from individual, collective and force level training continuum.

DESCRIPTION: As stated within the Command Vision for United States Cyber Command (USCC), the Department of Defense's cyber warriors conduct a full spectrum of daily operations in a contested, dynamically challenging cyberspace against near-peer competitors and adversaries. The outcomes of these operations are to ensure support for military operations, defend the nation against cyberattacks of serious consequence, and protect DoD information networks. As such in 2018, USCC, as a combatant command, announced 133 teams reaching full operational capability across USCC and Service Cyber Components for such missions.

As these teams have been rapidly built out, maintaining and enhancing readiness through realistic, high fidelity training is critical to projecting multi-domain military superiority across the full spectrum of conflict. As such, established to provide a standardized cyberspace operations training platform for the CMF, the Persistent Cyber Training Environment (PCTE) is spearheading the capability development of an on-demand, self-service enterprise training platform across cyber mission sets across individual-collective-force level training. As the CMF training platform, PCTE will enable CMF operators to plan-prepare-execute-assess on-demand training content, environments, tools, and datasets that can be readily re-used and shared across the DoD.

As CMF individuals and teams execute the training continuum lifecycle, PCTE will be utilized to plan, define, and deploy high fidelity training events consisting of virtualized instances of compute, network, and storage coupled with automated actors, realistic traffic profiles, key terrain, master scenario event list (MSEL) injects, cyber tools, intelligence artifacts, and assessment criterion to replicate real world conditions enabling cyber readiness. As such environments are defined and executed, a significant breadth and depth of digital activities transpire that are required to be collected, extracted, transformed, visualized and correlated to aggregate results, trends and playback/replay scenarios in order to obtain a more refined quantitative and qualitative understanding of achieving training objectives, standards, and conditions. Data sources within these environments include but are not limited to network traffic flow capture, node health state, in-range sensor instrumentation, operator activity, scenario injects/effects, collaboration methods, and observations against training objectives.

To date, many of these sources of datasets are individually and in stove-piped fashion captured that can potentially be collectively mined to more comprehensively understand performance, assessment, and collate after action reviews overtime with trends and predictions. Processing through machine language with artificial intelligence could potentially be applied to achieve an integrative data analytics and visualization capability tailored for cyber training.

Moreover, layered around the cyber event environment, the PCTE platform provides a suite of tools, applications, and repositories that are access by CMF operators whose data can be further accessed to understand over trends in popular tools, content, and assessment patterns across training profiles. The utilization of a big data platform and visualization applied to cyber training specific analytics and collective data interpretation would significantly add to understand individual, tea, and force level performance against training objectives and results across AAR playback, analysis, assessment, and trends/projections.

PHASE I: Phase 1 should perform a study to investigate concepts and approaches for leveraging, integrating, and applying big data analytics and visualization technologies for utilization within DoD CMF cyberspace operation training environments. The initial conceptual design should include means of storyboarding the problem set and walking through the plan-prepare-execute-assess process for cyber training events. Specific consideration across data sources, transformation, enrichment, storage, analytics, visualization and alerting should be addressed as well its application to cyber training across assessment, performance measurement, event monitoring/activity, and AAR/playback.

PHASE II: Phase 2 extends the deliverable concepts and approaches of big data analytics and visualization for cyber training environments and implements a proof-of-concept prototype that could be applied within the PCTE platform. Initial prototypes could be demonstrated within a standalone environment and gradually phased into the PCTE platform through agile scrum execution based on currently defined cyber training environment and scenarios. The prototype should consider specific aspects of Phase 1 investigation and demonstrate visualization dashboards, data feeds, aggregation, and correlation that provide deeper insight, results, and near-real time results and activity of CMF individuals and teams within cyber training environments and events across a variety of data sources. Additionally, trends and predictive analysis could also be demonstrated based on CMF operator use of specific content, injects, and other platform specific services, repositories, and tools to provide feedback on overall utilization metrics.

PHASE III DUAL USE APPLICATIONS: A big data analytics and visualization capability would have significant operational military applications and SBIR research transition prospects. As the DoD training platform, PCTE has the mission to provide tools and capabilities to measure, collect, warehouse, and provide data visualizations of on-demand training environments executed by CMF operators at individual, team, and force level continuum. Next, a number of corresponding cyber operational and even other DoD modeling and simulation (M&S) programs of record could leverage this effort for transition purposes. Commercial application for use within financial, cybersecurity, and gaming technologies could also be made.

REFERENCES:
1. Command Vision for US Cyber Command. "Achieve and Maintain Cyberspace Superiority." https://www.cybercom.mil/Portals/56/Documents/USCYBERCOM%20Vision%20April%202018.pdf?ver=2018-06-14-152556-010. April 2018.

2. USCYBERCOM. "2018 Cyberspace Strategy Symposium Proceedings." https://www.cybercom.mil/Portals/56/Documents/USCYBERCOM%20Cyberspace%20Strategy%20Symposium%20Proceedings%202018.pdf?ver=2018-07-11-092344-427. 2018.

3. Product Manager Cyber Resiliency and Training (PdM CRT). "Industry Day Briefing Slides." https://www.fbo.gov/index?s=opportunity&mode=form&id=3eafdf6598e8ce44ca9b7b11654a062b&tab=core&_cview=1. Dec 2018 and Jun 2019.

4. Defense Information Systems Agency (DISA). "Big Data Platform (BDP) and Cyber Situational Awareness Analytic Capabilities (CSAAC)." https://www.disa.mil/newsandevents/2016/Big-Data-Platform. 22 Apr 2016.

KEYWORDS: cyber, cyberspace, operations, big data, analytics, visualization, artificial intelligence, machine learning, extract, transform, load

A20-085 TITLE: Quantum Sciences Components for Space Applications

TECHNOLOGY AREA(S): Space Platforms

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop advanced quantum sciences communications components such as: high brightness entangled pair sources, photon counting detectors, quantum random number generators, optical components, subsystems, and systems for applications in the space environment (low Earth orbit to geosynchronous Earth orbit).

DESCRIPTION: Future Army communications systems will be implemented in a harsh adversarial environment whereas encryption hardware and algorithms will be required. Following the onset of future quantum computational systems modern day encryption and communication systems will be at risk. A potential solution to secure high bandwidth communications is quantum entanglement based optical communications channels. For these quantum channels to exist future satellite networks must contain such systems. Therefore, space environment hardened long lifecycle components for quantum communications must be developed.
The challenge is to develop advanced quantum entanglement components and experiments for communications networks that can survive in space. The specific technical challenges to be addressed include:
• violation of Bell's inequality
• Data teleportation
• Quantum key distribution (QKD) and entanglement based protocols
• Quantum state tomography
While these components and experiments may be at low technology readiness levels (TRL) in Phase I it is expected that a pathway to TRL maturation will be achieved through Phase II with potential flight experiments in Phase III. A goal of this SBIR is to develop components and/or subsystems and systems that will enable a demonstration of

entanglement based high bandwidth encrypted communications between space based satellites.

PHASE I: The phase I effort will result in analysis and design of the proposed components and experiments. The phase I effort shall include a final report with modeling, simulation, and/or experimental results supporting performance claims. The method for performing entanglement based communications will be documented.

PHASE II: The Phase I designs will be utilized to fabricate, test and evaluate a breadboard system. The designs will then be modified as necessary to produce a final prototype for flight qualification testing. Flight qualification testing can be proposed as a Phase II option. The final prototypes will be demonstrated to highlight the specific capabilities and performance in meeting the technical challenges. A complete demonstration system (of the breadboard and/or prototype system(s)) must also be provided by the offeror. At the end of the Phase II flight qualification option it is expected that the prototype will be at TRL 6.

PHASE III DUAL USE APPLICATIONS: Civil, commercial and military applications include high bandwidth secure site-to-site communications channels. The Phase III effort would be to design and build a flight experiment payload to demonstrate the particular proposed performance characteristics on an orbiting platform (i.e., small satellite, ISS platform, other). Military funding for this Phase III effort would be executed by the US Army Space and Missile Defense Technical Center as part of its Quantum Entanglement and Space Technology research.

REFERENCES:

1. "Tiangong2". chinaspacereport.com. China Space Report. 28 April 2017. Retrieved 12 Nov 2017.

2. Lin Xing (16 August 2016). "China launches world's first quantum science satellite". Physics World. Institute of Physics. Retrieved 17 August 2016.

3. F. J. Duarte, T. S. Taylor, Quantum entanglement physics secures space-to-space interferometric communications, Laser Focus World, pp 54-58, April (2015)

4. Wall, Mike (16 August 2016). "China Launches Pioneering 'Hack-Proof' Quantum-Communications Satellite". Space.com. Purch. Retrieved 17 August2016.

KEYWORDS: high brightness entangled pair sources, photon counting detectors, quantum random number generators, optical components

A20-086 TITLE: Small Satellite Components for Space Applications

TECHNOLOGY AREA(S): Space Platforms

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop small satellite technology components and subsystems for use in Low Earth Orbit (LEO).

DESCRIPTION: The appeal of small satellites as a low-cost, rapid-development approach to achieving a new on-orbit capability has gained momentum over the last several years. Future Army applications require constellations of multiple small satellites with various payloads and capabilities. The goal of this SBIR is to develop new and innovative components, subsystems, and systems for next generation small satellites.

The challenge is to develop components that can be packaged in a small satellite (12U or smaller) and operate in the harsh environment of space for extended lifecycles without sacrificing performance. The specific technical challenges to be addressed include:

- Low power, high data throughput Field Programmable Gate Array (FPGA) flight computers
- Low power digital camera systems
- Non-volatile solid state memory
- Guidance, Navigation, and Control systems, subsystems, and components
- Software Defined Radio
- Other Communications Components (i.e., antennas, amplifiers, optical, other)

While these components and experiments may be at low technology readiness levels (TRL) in Phase I it is expected that a pathway to TRL maturation will be achieved through Phase II with potential flight experiments in Phase III. A goal of this SBIR is to develop components and/or subsystems and systems that will enable a demonstration of the technical challenge(s) addressed by the proposed in a spaceflight experiment.

PHASE I: The phase I effort will result in analysis and design of the proposed components and experiments. The phase I effort shall include a final report with modeling, simulation, and/or experimental results supporting performance claims. The method for performing the technical challenges will be documented.

PHASE II: The Phase I designs will be utilized to fabricate, test and evaluate a breadboard system. The designs will then be modified as necessary to produce a final prototype for flight qualification testing. Flight qualification testing can be proposed as a Phase II option. The final prototypes will be demonstrated to highlight the specific capabilities and performance in meeting the technical challenges. A complete demonstration system (of the breadboard and/or prototype system(s)) must also be provided by the offeror. At the end of the Phase II flight qualification option it is expected that the prototype will be at TRL 6.

PHASE III DUAL USE APPLICATIONS: Civil, commercial and military applications include small satellite constellations. The Phase III effort would be to design and build a flight experiment payload to demonstrate the particular proposed performance characteristics on an orbiting platform (i.e., small satellite, ISS platform, other). Military funding for this Phase III effort would be executed by the US Army Space and Missile Defense Technical Center as part of its Quantum Entanglement and Space Technology research.

REFERENCES:
1. "Small Spacecraft Technology State of the Art," NASA Mission Design Division – Ames Research Center, Moffett Field, CA, Tech Rep NASA/TP-2015-216648/REV1, December 2015.

2. "Achieving Science with CubeSats: Thinking Inside the Box," Division on Engineering and Physical Sciences, National Academies of Sciences, Engineering, and Medicine, National Academies Press, 2016.

3. F. J. Duarte, T. S. Taylor, Quantum entanglement physics secures space-to-space interferometric communications, Laser Focus World, pp 54-58, April (2015)

KEYWORDS: Small satellite, Low power, high data throughput Field Programmable Gate Array (FPGA) flight computers, Low power digital camera systems, Non-volatile solid state memory, Guidance, Navigation, and Control systems, subsystems, and components, Software Defined Radio, Other Communications Components (i.e., antennas, amplifiers, optical, other)

A20-087 TITLE: Compact, Hemispherical Coverage Early Warning Detection and Track Sensor for Multi-Mission Applications

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop a low-cost, compact early warning detection and tracking system for target tracking in support of mobile Army tactical platforms.

DESCRIPTION: Many military weapon systems rely on radar technology that is on a different platform as an early warning detection and tracking system. Difficulties with this method arise in the radar handover latency being too long relative to the incoming threat trajectory, and target location errors in having the cueing radar on a different platform. A more favorable approach is to have a small, lightweight early warning threat detection system onboard the tactical platform housing the defensive weapon system. Low-cost compact radar technology has seen improvements in recent years, however complete hemispherical coverage is still problematic without requiring a large gimbal or multiple panels. Optical sensor options have been considered, but research, development, and experimentation are still required before this type technology would be transitioned to a weapon system. Optical sensor concepts for this type application may include a specialty hemispherical shaped lens that is capable of collecting am image from a full hemisphere and reshaping it onto a focal plane array.

The early warning detection sensor must be a subsystem on a platform with a defensive type weapon system such as a high energy laser, and therefore must have a small footprint. The entire volume of the system shall be less than Threshold: 5 cubic feet and Objective: 3 cubic feet. The system must be capable of detecting rockets, artillery, and mortars (RAM); group 1-3 Unmanned Ariel Systems (UASs), cruise missiles, rocket propelled grenades (RPGs), and Man-portable air-defense systems (MANPADs).

If successful, low-cost reduced SWaP early warning detection systems would significantly benefit many military and commercial applications such as High Energy Laser weapon platforms, small-satellite tracking applications, and the commercial aviation industry.

Requirements:

- FOV (Search Volume) - T: 180°; O: full hemispherical
- Track rate – T: 10 Hz; O: 50 Hz
- Angular Accuracy – T: 5 milliradian; O: 0.5 milliradian
- Volume (including electronics)– T: 8 cubic feet; O: 3 cubic feet
- Power Consumption – T: 1kW; O: 500W
- Time of day operation – T: day; O: day and night
- Targets and detection ranges:
    - -RAM – T: 5 km; O:10 km
    - -UASs – T: Group 1 at 3 km, Group 3 at 18 km; O: Group 2 at 10 km, Group 3 at 30 km
    - -Cruise Missile – T: 8 km; O: 18 km
    - -RPGs – T: 2 km; O: 5 km
    - -MANPADs – T: 2 km; O: 5 km

PHASE I: The phase I effort will result in the analysis and design the early warning detection system. Successful completion of the Phase I effort shall be a concept design that provides a high confidence in meeting the system requirements. Modeling and simulation, and / or laboratory experimentation shall be used to show efficacy of the concept design.

PHASE II: The Phase I designs will be utilized to fabricate, test and evaluate a breadboard system. The designs will then be modified as necessary to produce a final prototype. The final prototype will be demonstrated to highlight acquisition and tracking performance parameters.

PHASE III DUAL USE APPLICATIONS: Civil, commercial and military applications include short-range counter-RAM and UAV target tracking, remote sensing, small-satellite tracking, satellite communication, and other communication efforts. High energy laser weapons offer benefits of graduated lethality, rapid deployment to counter time-sensitive targets, and the ability to deliver significant force either at great distance or to nearby threats with high accuracy for minimal collateral damage. Future laser weapon applications will range from very high power devices used for air defense (to detect, track, and destroy incoming rockets, artillery, and mortars) to modest power devices used for counter-ISR. The Phase III effort would be to design and build a sensor that could be integrated into an Army's High Energy Laser Weapon System for real time use as part of the fire control system. Military funding for this Phase III effort would be executed by the US Army Space and Missile Defense Technical Center as part of its Directed Energy research.

REFERENCES:
1. P. A. Isaksen, E. Lovli "Multi Pulse Sweep System A New Generation Radar System," Radar 97, 14 - 16 October 1997, Publication No. 449, lEE 1997

2. D. M. Vavriv, V. A. Volkov, S. V. Sosnytskiy, A. V. Shevchenko, R. V. Kozhyn, A. A. Kravtsov, M. P. Vasilevskiy, D. I. Zaikin, "Development and Surveillance and Tracking Radar," IEEE, Ultrawideband and Ultrashort Impulse Signals, 18-22 September, 2006, Sevastopol, Ukraine pp. 26-31

3. Yi-cheng Jiang, Chun-xi Yu, "A Novel Approach for Angle Measuring Improvement in Monopulse Tracking," IEEE, Sixth International Conference on Fuzzy Systems and Knowledge Discovery, 2009

4. Y. Zhang, W. Zhai, X Zhang, X. Shi, X Gu, J. Jiang, "Moving target imaging by both Ka-band and Ku-band high-resolution Radars," SAR Image Analysis, Modeling, and Techniques XI, Proc. of SPIE Vol. 8179, 81790R, 2011

5. H. Zhou, F. Aryanfar, "A Planar Ka-Band Phased Array with Configurable Polarizations," IEEE, 978-1-4673-5317-5/13, Pg 1638-1639, AP-S 2013

6. Ann Marie Raynal*, Douglas L. Bickel, Michael M. Denton, Wallace J. Bow, Armin W. Doerryl, "Radar Cross Section Statistics of Ground Vehicles at Ku-band," Radar Sensor Technology XV, Proc. of SPIE Vol. 8021, 80210E, 2010

7. D. W. Kang, J. G. Kim, B. W. Min, G. M. Rebeiz, "Single and Four-Element Ka-Band Transmit/Receive Phased-Array Silicon RFICs With 5-bit Amplitude and Phase Control," IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 57, NO. 12, DECEMBER 2009

8. A. J. Abumunshar, W. Yeo, N. K. Nahar, D. J. Hyman, and K. Sertel, "Tightly Coupled Ka-Band Phased Array Antenna with Integrated MEMS Phase Shifters," IEEE, URSI 2014

9. B. W. Min, G. M. Rebeiz , "Single-Ended and Differential Ka-Band BiCMOS Phased Array Front-Ends," IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. 43, NO. 10, OCTOBER 2008

10. A. Vosoogh, K. Keyghobad, A. Khaleghi, S. Mansouri , "A High-Efficiency Ku-Band Reflectarray Antenna Using Single-Layer Multiresonance Elements," IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 13, 2014

KEYWORDS: Phased Array radar; Interferometric radar; Flat Panel; all-sky sensor; infrared sensors,

A20-088 TITLE: High Power Coherent Beam Combined Laser for Army Platforms

TECHNOLOGY AREA(S): Weapons

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop a high-power laser system with high beam quality utilizing coherent beam combination methods.

DESCRIPTION: Current HEL Weapon System demonstrators are primarily using spectrally beam combined fiber laser technology. Laser system output powers are pushing towards the 100 kilowatt threshold and all of that laser power must be combined via a physical beam-combining element. Beam combining elements, as well as the optical beam control systems, are rapidly approaching the physical limit of how much power they can handle before damage occurs. Similarly, as the Army explores options of integrating laser systems onto smaller, more compact platforms, the overall footprint of the laser source must decrease. A potential approach to overcoming these two limitations is to switch to a coherently combined laser system. Tiled aperture designs and monolithic filled-aperture designs each present intriguing advantages; one completely eliminates the need for individual optical elements to handle tens of kilowatts of power, while the other avoids the fill-factor losses associated with tiled arrays. Current platforms integrating lasers are finding that the predominant SWaP driver is the thermal management system of the laser. Obtaining electrical to optical efficiencies over 65% would enable integration onto previously unfeasible platforms but current fiber-based systems fundamentally will struggle to reach this objective. Resent results suggest that a laser system consisting of multitude of diodes with coherent combination between individual channels could be scaled up to the kilowatt-class level while maintaining efficiencies and SWaP superior to fiber-based lasers. These systems still have hurdles to overcome in beam quality and consistent mass manufacturing. This solicitation looks for a solution to achieve all parameters in one prototype:

- Continuous Wave Power Output: Threshold: 15 kW; Objective: 60 kW
- Electrical to Optical Efficiency: Threshold: 45%; Objective: 65%
- Beam Quality (M2): Threshold: 1.5; Objective: 1.1
- Wavelength: Wavelengths that transmit through the atmosphere

PHASE I: The phase I effort shall include analysis and design of the proposed laser architecture concept. The analysis shall provide confidence that the proposed concept design will be successful in meeting the specifications. Power, efficiency, and beam quality expectations out of the laser shall be addressed in the Phase I effort.

PHASE II: During phase II, the phase I designs will be utilized to fabricate, test and evaluate a laser system prototype. The power scaling potential, efficiency, and beam quality specifications shall be demonstrated during the phase II effort.

PHASE III DUAL USE APPLICATIONS: During phase III, the contractor will develop a 10s of kilowatt class coherently beam combined laser system and work with the government to integrate the technology into a laser weapon system. This coherently combined laser will be tested in one of the Army's high energy laser demonstrators or testbeds.

REFERENCES:
1. P. Albrodt et. al., "Coherent Combining of High Brightness Tapered Amplifiers for Efficient Non-Linear Conversion," 11 January 2019, Vol. 27, No. 2, OPTICS EXPRESS 928

2. P. Albrodt et. al., "Coherent Beam Combining of High-Power Tapered Amplifiers," 2017 IEEE High Power Diode Lasers and Systems Conference (HPD)

3. O. Andrusyak, V. Smirnov, G. Venus, V. Rotar, L. Glebov, "Spectral Combining and Coherent Coupling of Lasers by Volume Bragg Gratings," IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL. 15, NO. 2, MARCH/APRIL 2009

4. L. R. Brewer, "Highly coherent injection-locked laser diode arrays," 20 January 1991, Vol. 30, No. 3, APPLIED OPTICS

5. K. D. Choquette, M. T. Johnson, Z. Gao, B. Thompson, G. Ragunathan, S. T. M. Fryslie, M. P. Tan, D F. Siriani, "Coherent Coupling in Vertical Cavity Laser Arrays (Invited)," 978-1-4577-1504-4/14, 2014 IEEE

6. B. Liu, Y. Braiman, “Coherent beam combining of high power broad area laser diode array with near diffraction limited beam quality and high power conversion efficiency,” 16 December 2013, Vol. 21, No. 25, DOI:10.1364/OE.21.031218, OPTICS EXPRESS 31218

7. B. Liu, Y. Liu, and Y. Braiman, “Coherent addition of high power laser diode array with a V-shape external Talbot cavity,” 8 December 2008, Vol. 16, No. 25, OPTICS EXPRESS 20935

8. G. Lucas-Leclin, et. al., “Coherent Combining Architectures for High-Brightness Laser Diodes,” October 2017, hal-01737611, Pages 49-40, 2017 IEEE High Power Diode Lasers and Systems Conference (HPD), Coventry United Kingdom

9. S. M. Redmond, K. J. Creedon,1 J. E. Kansky, S. J. Augst, L. J. Missaggia, M. K. Connors, R. K. Huang, B. Chann, T. Y. Fan, G. W. Turner, A. Sanchez-Rubio, “Active coherent beam combining of diode lasers”, March 15, 2011, Vol. 36, No. 6, OPTICS LETTERS

10. Y. Zhao and L. Zhu, "On-chip coherent combining of angled-grating diode lasers toward bar-scale single-mode lasers," 12 March 2012, Vol. 20, No. 6, OPTICS EXPRESS 6375

KEYWORDS: coherently combined lasers, high energy lasers, high power fiber lasers, high power diode lasers

A20-089 TITLE: Tactical Beaconless Atmospheric Turbulence Measurements

TECHNOLOGY AREA(S): Weapons

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop a tactical beaconless atmospheric turbulence measurement system capable of measuring range resolved Cn2 over path lengths of 0.5 to 10 km with 10m range resolution.

The challenge is to create a tactical grade beaconless atmospheric turbulence measurement system capable of field deployment and measuring range resolved atmospheric turbulence Cn2 values over ranges of 0.5 to 10 km with a range resolution of 10m.

DESCRIPTION: As modern laser weapon systems begin to move into the field, measuring atmospheric turbulence for predicting the laser system effectiveness will be of great concern. Current methods of measuring turbulence include scintillometers, Shack Hartman Wavefront Sensors, and differential image motion monitor systems which require a beacon be placed down range and directed back toward a detector. Other methods use passive targets placed down range along with imaging systems to determine the level of turbulence. Placing a beacon or known available passive target downrange is not a feasible option for fielded systems, thus a single ended approach is needed.

The challenge is to create a tactical grade beaconless atmospheric turbulence measurement system capable of field deployment and measuring range resolved atmospheric turbulence Cn2 values over ranges of 0.5 to 10 km with a range resolution of 10m. The system should be ruggedized to withstand inclement weather in varied environments and should be capable of quantifying Cn2 in the range of 1x10^ - 16 < Cn2 < 1x10^ - 12. Although Cn2 can be derived from direct measurements of scintillation, wavefront phase aberration, localized wavefront tilt, or lidar backscatter, this topic is not limited to those types of approaches. An approach that uses local meteorological data along with real time atmospheric modeling and produces accurate results is also a viable solution.?

-Environment: Threshold: 24/7 Outdoor operation, Temperature 0-50C; Objective: 24/7 Outdoor operation, Temperature -15-60C
-Measurement Dynamic Range: Threshold: 1x10^ - 15 < Cn2 < 1x10^ - 12; Objective: 1x10^ - 16, Cn2 < 1x10^ - 12
-Measurement Range: Threshold: 1km < Rmax < 3km; Objective: 0.5km < Rmax < 10 km
-Range Resolution: Threshold: 100m; Objective: 10m
-Form Factor/Size/Weight: Threshold/Objective: Single Ended (no beacon or known available passive target) Tripod Mountable

PHASE I: The phase 1 effort will result in a trade study and final design of a new beaconless atmospheric turbulence measurement system capable of meeting measurement requirements.

PHASE II: The Phase I designs will be utilized to fabricate, test and evaluate a prototype system. The designs will then be modified as necessary to produce a final prototype. The final prototype will be demonstrated to highlight the effectiveness of measurements.

PHASE III DUAL USE APPLICATIONS: High energy DoD laser weapons offer benefits of graduated lethality, rapid deployment to counter time-sensitive targets, and the ability to deliver significant force either at great distance or to nearby threats with high accuracy for minimal collateral damage. Knowledge of the atmospheric turbulence along the shot path is a key limiting factor for lethality and as such it is a critical input for the fire control system. The Phase III effort shall be to design and build a sensor that could be integrated into an Army's High Energy Laser Weapon System for real time use as part of the fire control system. Military funding for this Phase III effort would be executed by the US Army Space and Missile Defense Technical Center as part of its Directed Energy research.

REFERENCES:
1. Richard L. Espinola, Jae Cha, Kevin Leonard, "Novel methodologies for the measurement of atmospheric turbulence effects," Proc. SPIE 7662, Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXI, 76620W (22 April 2010); doi: 10.1117/12.852294

2. Smalikho, I., Köpp, F. and Rahm, S. (2005). Measurement of Atmospheric Turbulence by 2-μm Doppler Lidar. Journal of Atmospheric and Oceanic Technology, 22(11), pp.1733–1747.

3. Humphreys, R.A., Primmerman, C.A., Bradley, L.C. and Herrmann, J. (1991). Atmospheric-turbulence measurements using a synthetic beacon in the mesospheric sodium layer. Optics Letters, [online] 16(18), p.1367. Available at: https://www.osapublishing.org/ol/abstract.cfm?uri=ol-16-18-1367 [Accessed 13 Jun. 2019].

4. Colin N. Reinhardt, D. Wayne, K. McBryde, G. Cauble, "Extracting atmospheric turbulence and aerosol characteristics from passive imagery," Proc. SPIE 8874, Laser Communication and Propagation through the Atmosphere and Oceans II, 88740F (25 September 2013); doi: 10.1117/12.2023382

KEYWORDS: High energy lasers, Atmospheric turbulence measurement, Atmospheric turbulence profiling

A20-090 TITLE: High Energy Laser Beam Absorption Diagnostics and Thermal Blooming Prediction System

TECHNOLOGY AREA(S): Weapons

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions.

Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop an atmospheric absorption spectroscopy measurement system capable of measuring the absorption properties of atmospheric gases and particles in the 1000-1100 nanometer near infrared wavelength band, and predict the occurrence and degree of thermal blooming due to high energy laser beam propagation.

DESCRIPTION: The objective of this effort is to create a portable measurement system to characterize the spectral absorption in numerous deployable environments over the wavelengths of 1030 – 1080nm, and make predictions on thermal blooming effects. These measurements will be utilized to characterize the specific mechanisms that give rise to thermal blooming as well as to determine the maximum amount of laser energy that can be utilized for a given engagement before thermal blooming effects create diminishing returns on increased laser power. Since the instrumentation will be used in the field, it must be designed such that it is immune to the effects of turbulence which can be severe over long near ground paths. The measurement path length must be optimized to balance the need for adequate atmospheric sampling, measurement accuracy, and immunity to turbulence. The measurement system should be validated through modeling and laboratory experimentation before it is taken out of a controlled lab environment to support field tests. Below is a set of threshold and objective requirement for the final field test instrument.

Wavelength Range (nm): T: 1030-1070; O: 1000-1100
Spectral Resolution (nm): T: 0.1; O: 0.01
Absorption accuracy (%): T: 5; O: 1
Environment: T: 24/7 Outdoor operation, Temperature 0-50C; O: 24/7 Outdoor operation, Temperature -15-60C
Atmospheric Turbulence (worst case): T: Cn2 < 1x10^-13; O: Cn2 < 1x10^-12
Eye safety: Eye safe operation (no PPE required)
Size/Weight/Ruggedized: T: Field Test Transportable; O: Tripod Mountable

PHASE I: The phase I effort will focus on the design of measurement system and analysis of the thermal blooming prediction model theory. This effort should result in a preliminary design that has been analyzed using modeling and simulation to establish high confidence that the instrument will be capable of meeting the requirements in the field test environment described above, and the theoretical process for determining thermal blooming based on measurements from the system.

PHASE II: The Phase I designs will be utilized to fabricate, test and evaluate a breadboard system. The designs will then be modified as necessary to produce a final prototype. The final prototype will be demonstrated in a field test or controlled environmental chamber to validate its thermal blooming prediction accuracy.

PHASE III DUAL USE APPLICATIONS: High energy DoD laser weapons offer benefits of graduated lethality, rapid deployment to counter time-sensitive targets, and the ability to deliver significant force either at great distance or to nearby threats with high accuracy for minimal collateral damage. Future laser weapon applications will include very high power devices used for air defense to detect, track, and destroy incoming rockets, artillery, and mortars and it is expected that thermal blooming will be a significant limiting factor. The utilized laser power will need to be managed to keep it just below the level that would produce thermal blooming. The Phase III effort would be to design and build a sensor that could be integrated into an Army's High Energy Laser Weapon System for real time use as part of the fire control system. Military funding for this Phase III effort would be executed by the US Army Space and Missile Defense Technical Center as part of its Directed Energy research.

REFERENCES:
1. J. I. Steinfeld, "Molecules and Radiation: Introduction to Modern Molecular Spectroscopy", Dover Publications, (1974)

2. G.B. Rieker, et. al., "Frequency-comb-based remote sensing of greenhouse gases over kilometer air paths" Optica, 1, 5, 290 – 298, (2014)

3. L. S. Rothman, et. al., "The HITRAN2012 molecular spectroscopic database" Journal of Quantitative Spectroscopy and Radiative Transfer" 130, 4 – 50, (2013)

4. R. K. Tyson, “Principles of Adaptive Optics”, 30 – 50, CRC Press, (2012)

5. L. C. Andrews, R. L. Phillips “Laser Beam Propagation through Random Media”, SPIE Publications, (2005)

6. Griffith, D. W. T., Pöhler, D., Schmitt, S., Hammer, S., Vardag, S. N., and Platt, U.: Long open-path measurements of greenhouse gases in air using near-infrared Fourier transform spectroscopy, Atmos. Meas. Tech., 11, 1549-1563, https://doi.org/10.5194/amt-11-1549-2018, 2018.

KEYWORDS: High Energy Lasers, thermal blooming, Absorption spectroscopy, Spectral transmission, Spectrometer, Spectrophotometer

A20-091 TITLE: Tactical Ultrashort Pulsed Laser for Army Platforms

TECHNOLOGY AREA(S): Weapons

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop an ultrashort pulse laser (USPL) system with sufficient SWaP and ruggedization for use on Army relevant platforms.

DESCRIPTION: Current high energy laser (HEL) weapon systems primarily consist of continuous wave (CW) laser sources with output powers in the kilowatts. These kilowatt-class CW laser systems predominantly engage targets via absorption of light; either causing the target to burn and melt or overwhelming optical sensors with high intensities. Thanks to the emergence of diode and fiber laser technology, these laser systems have grown increasingly ruggedized to the point they have been integrated onto platforms ranging from ground to sea. The Army is preparing the warfighter for a future battlefield with rapidly modernizing militaries while new threats and gaps are emerging. CW lasers provide solutions to many of these problems but due to their fundamental different natures, lasers with pulse widths in the range of femtoseconds provide unique tactical capabilities due to their rapid discharge of enormous power. This call aims to develop an USPL that is ruggedized enough to begin testing in relevant Army environments. While most CW lasers simply melt targets, USPL systems are able to neutralize threats via three distinct mechanisms: ablation of material from the target, the blinding of sensors through broadband supercontinuum generation in the air, and the generation of a localized electronic interference used to overload a threat’s internal electronics. Even the propagation of light from a USPL system holds unique advantages. The sheer amount of intensity in a terawatt pulse laser is able to cause a non-linear effect in air resulting in a self-focusing filament. These filaments propagate without diffraction, providing a potential solution to the negative impact turbulence has on beam quality when propagating a conventional CW laser system. Differences in lethality as well as propagation mechanisms makes USPL technology one of particular interest for numerous mission sets. Over the last two decades, femtosecond lasers have gone from requiring dedicated buildings at national laboratories to sitting on academic optics tables across the country. These USPL advancements, while promising, still have many hurdles to overcome in SWaP, relevant operating environments, and consistent mass manufacturing. This solicitation looks for a solution to achieve the parameters listed below in one prototype:

- Wavelength: Wavelengths that transmit through the atmosphere
- Average Power Output: Threshold: 20 W; Objective: 50 W
- Pulse Peak Power: Threshold: 1 TW; Objective: 5 TW
- Pulse Width: Threshold: 200 fs; Objective: 30 fs
- Repetition Rate: Threshold: 20Hz; Objective: 50Hz

.	Beam Quality (M2): Threshold: 2.0, Objective 1.5

PHASE I: The phase I effort shall include analysis and design of the proposed laser architecture concept. The analysis shall provide confidence that the proposed concept design will be successful in meeting the specifications. The expectations for the above specifications out of the laser shall be addressed in the Phase I effort.

PHASE II: During phase II, the phase I designs will be utilized to fabricate, test and evaluate the laser system prototype. The above specifications of interest shall be demonstrated and measured during the phase II effort, or a detailed design for a prototype that will realize all parameters shall be delivered.

PHASE III DUAL USE APPLICATIONS: During phase III, the contractor will work with the government to complete a USPL system that meets all requirements and integrate the technology into a laser system. This laser system will be tested in one of the Army's high energy laser demonstrators or testbeds.

REFERENCES:
1. N. Azobek, M. Scalora, C.M. Bowden, and S.L. Chin, "White-Light Continuum Generation and Filamentation During the Propagation of Ultra-Short Laser Pulses in Air," 8 May 2001, Vol. 191, Pages 353-362, Optics Communications

2. R. Budriunas et. al., "53 W Average Power CEP-Stabilized OPCPA System Delivering 5.5 TW Few Cycle Pulses at 1 kHz Repetition Rate," 3 March 2017, Vol. 25, No. 5, OPTICS EXPRESS 5797

3. M. Chateauneuf, S. Payeur, J. Dubois, and J.-C. Kieffer, "Microwave Guiding in Air by a Cylindrical Filament Array Waveguide," 3 March 2008, Vol. 92, Applied Physics Letters 091104

4. H. Cao et. al., "Active Spectral Shaping with Polarization Encoded Ti:Sapphire Amplifers for sub-20 fs Multi-Terawatt Systems," 27 February 2018, Vol. 15, Laser Physics Letters 045003

5. S.L. Chin et. al., "Filamentation of Femtosecond Laser Pulses in Turbulent Air," 29 November 2001, Vol. 74, Pages 67-76, Applied Physics B

6. P. Ding et. al., "Backward Lasing of Air Plasma Pumped by Circularly Polarized Femtosecond Pulses for the Sake of Remote Sensing (BLACK)," 1 December 2014, Vol. 22, No. 24, OPTICS EXPRESS 29965

7. R. Flender et. al., "Control of THz Field Waveform Emitted from Air Plasma by Chirping Two-Color Laser Pulses," 7 December 2018, Vol. 436, Pages 222-236, Optics Communications

8. P. R. Hemmer et. al., "Standoff Spectroscopy via Remote Generatoin of a Backward-Propagating Laser Beam," 22 February 2011, Vol. 108, No. 8, Pages 3130-3134, PNAS

9. J. Kasparian, J.P. Wolf, "Physics and Applications of Atmospheric Nonlinear Optics and Filamentation," 7 January 2008, Vol. 16, No. 1, OPTICS EXPRESS 466

KEYWORDS: ultrashort pulse lasers, USPL, high energy lasers, femtosecond lasers, pulsed laser sytsem

A20-092	TITLE: Intelligent Lithium-ion 6T MIL-PRF-32565 Compliant Battery Maintenance & Charging System

TECHNOLOGY AREA(S): Ground/Sea Vehicles

OBJECTIVE: An advanced, intelligent Lithium-ion 6T MIL-PRF-32565 Compliant Battery Maintenance & Charging System.

DESCRIPTION: The 28-V Lithium-ion 6T drop-in replacement battery (Li-ion 6T) is a critical technology to enhance energy storage to improve warfighting performance across the Army, Marines, and Navy. The Li-ion 6T is a drop-in replacement for legacy Lead-Acid 6T batteries for starting, lighting, and ignition (SLI) and silent-watch applications, and provides the same form, fit, and expanded function, including increased silent watch time, significantly extended cycle life, and faster recharge time. Currently fielded Lead-Acid 6TAGM battery chargers and maintenance equipment have limited or no compatibility with Li-ion 6T batteries, in part due to differences in battery chemistry and voltage levels (12V vs. 24V). Additionally, fielded charger solutions for Lead-Acid typically lack sophistication in charging method, usually only providing different preset charging voltage levels, and do not provide enhanced prognostics/diagnostics or CAN communication required for interfacing with modern, smart batteries. Accordingly, an intelligent Li-ion 6T MIL-PRF-32565 Compliant Battery Maintenance & Charging System (hereafter referred to just as "charger") is required to improve the field supportability, charging, and maintenance of Li-ion 6T batteries as well as to enable enhanced capabilities such as optimized charging per battery vendor/type, optimized charging for a given vehicle/mission, discharging to a preset SOC for storage & transport, advanced prognostics/diagnostics, detection of faults & manufacturing defects, bi-directional battery-to-charger CAN communication, equalization, and updating battery firmware over CAN bus (MIL-PRF-32565 Sections 3.6.4.8, A.5.3). Technology developed should be compatible with all MIL-PRF-32565 compliant Li-ion 6T products and generally applicable to low-voltage commercial Li-ion battery packs. The technology shall also aide the user in selection of optimal sets of Li-ion 6T batteries for a given vehicle platform and mission as well as identify deficit batteries or batteries in need of replacement. The technology shall be capable of optimally charging Li-ion 6T batteries individually as well as in full vehicle sets of up to six Li-ion 6Ts. The charger shall be MIL-STD-1275 compliant, shall support charging/discharging of both Type I and Type II batteries, and shall allow for bi-directional transfer of power between batteries for high efficiency and reducing losses. The charger shall be military ruggedized, designed for operation over the entire military temperature range, and include a human interface (graphical) that considers human factors. The charger shall be capable of providing external power to the battery's BMS through the battery power terminals (3.6.2). In support of prognostics, the charger shall additionally verify functionality of battery safety protections (3.6.3.3) as well as the resolution/error of the performance characteristics of MIL-PRF-32565 Table IV. The Phase II chargers shall additionally be capable of receiving and transmitting all messages and signals required to communicate with the battery in Appendix A of MIL-PRF-32565 and shall meet the requirements of SAE J1939 and ISO 11898, while providing variable baud rates and termination resistances where necessary. The charger shall interface with the MIL-DTL-38999 receptacle on the Li-ion 6T battery.

PHASE I: Identify and determine the engineering, technology, and hardware and software needed to develop this concept. Additionally, sophisticated novel charging/discharging techniques & methods should also be developed in this Phase to be employed in Phase II to achieve standard and rapid charging (4.4.9, 4.4.9.2) while producing the most benign impact to cycle life and supporting a range of turnaround times as the mission requires. These techniques & methods should make use of relevant parameters transmitted by the smart battery and should be adapted as necessary to optimize charge, discharge, and equalization for a given battery vendor, type, and chemistry. Bench top testing of a Phase I embedded hardware and software charger prototype for one Li-ion 6T battery is expected. Drawings showing realistic designs based on engineering studies are expected deliverables. Additionally, modeling and simulation (M&S) tools needed to drive the technology is expected. A bill of materials and volume part costs for the Phase I designs should also be developed. Designs in this phase also need to address the challenges and requirements identified in the above description as well as the charger requirements of Phase II.

PHASE II: Develop and integrate prototype hardware and software into intelligent Li-ion 6T MIL-PRF-32565 Compliant Battery Maintenance & Charging Systems (Phase II chargers) using the designs and technologies developed in Phase I. The technology shall be designed such that it is generally applicable to all MIL-PRF-compliant Li-ion 6T batteries (and low-voltage Li-ion batteries generally), but must be tested and demonstrated on at least two different Li-ion 6T battery variants. The chargers shall accommodate a variety of input source voltages (ex: 120/208/240VAC single/three phase, 20-60 VDC), including connection to a Tactical Quiet Generator (TQG). Deliverables shall include electrical drawings and technical specifications, software, M&S and test results, and at least two Phase II chargers, each capable of charging at least six batteries. The Phase II chargers shall include the ability to (1) read and use manufacturer specific parameters for charge/discharge optimization; (2) set battery baud rates (A.3.3.5); (3) capture and log long-term fault data (3.6.8) and short-term fault data (3.6.9) for reporting and improving the chargers' Li-ion 6T prognostics/diagnostics; (4) check the hardware and software version of the battery (3.6.5.3.4); (5) execute built-in test; (6) read and reset DTC trouble code faults and failures (3.6.5.3.3); (7) perform configuration overwrite (A.5.5); (8) set the transportability command, SOC reserve limit, application overcurrent limits, and application overcurrent periods (A.5.7.1-3); and (9) read in the maximum charge current and bus voltage request signals for optimization of charging functions (3.6.5.1.5, 3.6.5.1.7). The charger shall be capable of control of battery state transitions through CAN commands and charger output connections, including Operation, Standby, Maintenance, Protected, and Dormant State (3.6.6). The charger shall be capable of powering and controlling via CAN (enabling/disabling) the battery's internal automatic heater function to allow heating of the battery to the temperature required for optimum charging for a given set of charge conditions (3.3.5.2.3). The charger shall be capable of altering the state of the battery contactor via CAN bus (3.6.3.5). The charger shall be capable of mimicking the master power switch (On and Off states) and reset pin as well as acting as a virtual master power switch (A.3.3.3.1, A.3.3.7). The charger shall be capable of placing the battery into battle override mode (3.3.6) to allow for repair of faults that can be safely corrected through charge/discharge operations. A bill of materials and volume part costs for the Phase II design should also be developed.

PHASE III DUAL USE APPLICATIONS: This phase will begin installation and integration of the solutions developed in Phase II into military grade Li-ion 6T chargers as well as commercial low-voltage Li-ion chargers.

REFERENCES:

1. Seo, Minhwan, et al. "Detection Method for Soft Internal Short Circuit in Lithium-Ion Battery Pack by Extracting Open Circuit Voltage of Faulted Cell." Energies (19961073) 11.7 (2018).

2. "Performance Specification: Battery, Rechargeable, Sealed, 6T Lithium-ion," MIL-PRF-32565, https://assist.dla.mil.

3. "Department of Defense Interface Standard, Characteristics of 28 Volt DC Input Power to Utilization Equipment in Military Vehicles, MIL-STD-1275, https://assist.dla.mil.

4. Peng, Bo-Ruei, et al. "A Li-ion battery charger based on remaining capacity with fuzzy temperature control." 2016 IEEE/ACIS 15th International Conference on Computer and Information Science (ICIS). IEEE, 2016.

5. Liu, Yi-Hwa, and Yi-Feng Luo. "Search for an optimal rapid-charging pattern for Li-ion batteries using the Taguchi approach." IEEE Transactions on Industrial Electronics 57.12 (2010): 3963-3971.

6. Nuhic, Adnan, et al. "Health diagnosis and remaining useful life prognostics of lithium-ion batteries using data-driven methods." Journal of power sources 239 (2013): 680-688.

KEYWORDS: Lithium-ion, 6T, charger, CAN Bus, batteries, power, energy, maintenance

A20-093 TITLE: Multifunctional Metamaterials for Novel Interaction with the Environment

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Develop multifunctional metamaterials (MFM) which exploit the electromagnetic (EM) spectrum or energy for novel environmental interactions. Novel environmental interactions include (but are not limited to) EM wave guidance, absorption, negative permittivity, negative permeability, and EM stimulated mechanical resonance or oscillation.

DESCRIPTION: Multifunctional Metamaterials (MFM) can harness, direct and control the propagation and transmission of certain aspects of the EM spectrum. There is a need for novel materials that can manipulate the paths traversed by visible light and other frequencies of the EM spectrum, including infrared (IR) and microwaves, alter their reflection and refraction, and enhance material properties for combat applications. MFMs are defined as artificially structured organic, metallic, ceramic, or composites of many materials which interact with the EM spectrum and exhibit behaviors that do not readily occur in nature. The proposers should demonstrate MFMs that control EM radiation by absorbing or guiding an incident wave around an object, without being affected and/or reflected by the object. Metamaterials should be engineered with arbitrarily assigned positive or negative values of permittivity and permeability, which can also be independently varied at will. The proposers should demonstrate the capability to build metamaterial based devices, adaptable to a broad spectrum of radiated light. The proposers should demonstrate materials and techniques that produce strong scattering suppression in all directions and over a broad bandwidth of operation.

PHASE I: Phase I should demonstrate the innovation, the scientific and technical merit, the feasibility, and commercial merit of selected concepts. The proposers should identify and explore novel multifunctional metamaterials with one or many of the attributes such as negative reflective and refractive index across the electromagnetic spectrum, wave absorption, wave guidance, which enhance vehicle protection and performance. Metrics of interest for Phase 1 include percentage of EM energy absorbed, reflected, refracted at visible light frequencies and other frequencies of the EM spectrum, including infrared (IR) and microwaves; and measureable changes in MFM physical properties when under EM radiation and when not. Prototype samples, modeling and simulation (M&S), or other rigorous and scientifically sound methods should be used to demonstrate MFM performance along the stated metrics of interest. Prototype samples, models and data are an expected deliverable and include mathematical formulae and/or scientific M&S results.

PHASE II: Phase II should culminate in well-defined deliverable prototype(s) (technologies or materials) which meet the requirements of the original solicitation topic. Prototype(s) should manipulate the paths traversed by light and other EM frequencies, alter their reflection and refraction, and/or create effects which enhance material properties for combat applications.
Deliverables should include technical drawings and specifications, mathematical formulas, M&S and test results, and prototype(s) of MFMs. The measurable metrics of the metamaterials' performance should include the changes in refraction, reflection index and scattering. The first prototype should be delivered at the end of the first year of Phase II SBIR. The second prototype should achieve a significant performance improvement of the first year's prototype. The second prototype should be delivered at the end of the second year of Phase II SBIR and also include recommendations for large-scale manufacturing. Improved life cycle and performance models from Phase I are also expected deliverables. Testing of the Phase II designs should include benchtop testing of Phase II prototypes. Testing of the Phase II designs should also include system level testing of prototypes at Ground Vehicle Systems Center (CVSC) of Combat Capabilities Development Command (CCDC). Phase 2 performance metrics of interest include, but are not limited to a prototype MFM sample with the claimed environmental interactions from Phase 1 (% EM refractivity, % EM reflectivity, % EM absorption, etc.), MFM-mass cost at scale (i.e $/kg or $/ton), areal cost at scale (i.e. $/sqft or $/m2).

PHASE III DUAL USE APPLICATIONS: Proposers could partner with the industry to build and implement novel materials and manufacturing techniques which make vehicles more or less visible on the road. These are all commercially viable benefits of this topic. Possible applications include: road safety, law enforcement, intelligence, rescue and training aids. This is a dual-use technology applicable for government and private industry use.

REFERENCES:
1. Shalaev, V. M. (2008) "PHYSICS: Transforming Light". Science. 322 (5900): 384-386.

2. Pendry, J.B.; Schurig, D.; Smith, D. R. (2006). "Controlling Electromagnetic Fields", Science, 312 (5514): 1780–1782

3. Chen, Huanyang; C. T. Chan, C.T. and Sheng, Ping (April 23, 2010). "Transformation optics and metamaterials". Nature Materials, 9 (5): 387–396

4. Smith, D. R.; Padilla, Willie; Vier, D.; Nemat-Nasser, S.; Schultz, S. (2000). "Composite Medium with Simultaneously Negative Permeability and Permittivity", Physical Review Letters, 84 (18): 4184–7.

5. Padilla, Willie J.; Smith, David R.; Basov, Dimitri N. (2006-03-01). "Spectroscopy of metamaterials from infrared to optical frequencies" (PDF). JOSA B. 23 (3): 404–414.

6. S. Pais, "Craft using an inertial mass reduction device", Patent No.: US 10,144,532 B2, Dec. 4, 2018.

7. M. Gao, Z. Wu, Z. Wen, Effective Negative Mass Nonlinear Acoustic Metamaterial with Pure Cubic Oscillator, Advances in Civil Engineering, Vol. 2018, Article ID 3081783, 15 pp.

KEYWORDS: metamaterials, transformation optics, negative permeability, negative permittivity, negative refraction index, scattering, invisibility, inertial mass reduction, mechanical resonance or oscillation

A20-094 TITLE: Autonomous Trailer Hitch Couple/Decouple

TECHNOLOGY AREA(S): Ground/Sea Vehicles

OBJECTIVE: Develop an automated trailer coupling/decoupling system that can be integrated on to both current autonomous systems such as Expedited Leader Follower and Autonomous Ground Resupply, as well as Next Generation Autonomous Systems.

DESCRIPTION: Trailers provide the capability to increase throughput by transporting mission essential equipment and supplies including weapons systems, equipment, tactical power, water and ammunition. Connecting to trailers is an aggravating task, made more difficult by tough terrain and weather conditions. Developing/implementing an autonomous hitch can make a dangerous, time-consuming and manpower intensive task a one-person operation that can be done in a much shorter time period. This SBIR is looking for innovative ways to automate trailer coupling/decoupling. Ideally the system will be a simple installation onto the existing Military convoy vehicle fleet currently being utilized in various soldier tested autonomous convoy vehicle technology/capability demonstrations. Low-cost, high reliability sensors are critical for reliable autonomous hitch performance especially given the mission profiles experienced during autonomous convoy vehicle operations over rough terrain and high speeds.

This SBIR is linked to Ground Vehicle Robotics (GVR) Expedited Leader Follower (ExLF) and Autonomous Ground Resupply (AGR) Science and Technology Objective (STO) programs, providing additional autonomous vehicle capability to enhance vehicle autonomy operations to support automated convoy vehicle performance. ExLF and AGR are currently adding the capability to integrate trailers in forward and reverse directions as part of a semi-autonomous convoy. Adding the capability to autonomously couple and decouple a trailer will work to automate a dangerous, time consuming and manpower intensive task. The topic will implement innovative solutions to allow for a PLS vehicle to autonomously connect the pintle hitch and power/air/data lines of a M1076 trailer to fully automate trailer coupling/decoupling. There is an opportunity to demonstrate this capability as part of AGR Increment 3 Soldier experiment in FY21; ultimately transitioning the capability to inform the Leader Follower Program of Record.

PHASE I: Determine the feasibility of an optimal autonomous trailer hitch sensor suite that can engage/disengage with an autonomous vehicle. Develop simplied soldier controls for activating/monitoring autonomous trailer hitch process/operations. Develop system that requires minimal base vehicle modification/installation. Conduct autonomous trailer hitch simulations with integrated virtual sensors to refine autonomous trailer hitch design/operation. Design hitch capable of 3-axis articulation to allow for non-exact vehicle/trailer alignment. Develop hitch capable of interfacing/supporting FMTV/PLS vehicles and able to support Gross Trailer Weight Rating of 3000lbs and Tongue Weight Rating of 3,000lbs. Generate a technical report documenting above analysis/evaluation/integration of autonomous trailer hitch capability.

PHASE II: Create a prototype of autonomous trailer hitch system and evaluate in relevant scenarios/applications on representative base vehicles. Integrate optimal autonomous trailer hitch sensors identified/evaluated in Phase I on a representative base vehicle. Conduct autonomous trailer hitch testing throughout a variety of vehicle configurations/conditions and reevaluate/confirm previously selected optimal sensors. Optimize autonomous trailer hitch system with regards to performance, cost, reliability, ease of integration, etc. Incorporate a pintle that is moveable both laterally and longitudinally to permit a single operator to hook-up to a M1076 PLS trailer. Hook-up shall be with the trailer tongue offset laterally up to 12 to 18 inches from the centerline of the truck and 12 to 18 inches aft of the towing position. The pintle shall be capable of towing all lunette style trailers in common use with 2-1/2, 5, and 10 ton vehicles.

PHASE III DUAL USE APPLICATIONS: Transition autonomous trailer hitch system onto current/future targeted Military autonomous systems, including Expedient Leader-Follower/AGR, etc. Transition system into commercial market segments that would benefit or are currently utilizing trailers during normal operations, such as recreational vehicles, tractors, semi-trailers, etc.

REFERENCES:
1. http://www.teleswivel.com/

2. https://www.motor1.com/news/315320/autonomous-trailer-hitching-patent-filing/

3. http://www.freepatentsonline.com/y2016/0243908.html

4. http://www.freepatentsonline.com/y2018/0222264.html

5. https://patents.google.com/patent/WO2017220257A1/en

6. http://folk.ntnu.no/skoge/prost/proceedings/ifac2014/media/files/0437.pdf

7. https://press.zf.com/press/en/media/media_695.html

KEYWORDS: Autonomous, ground, resupply, expedited, leader, follower, trailer, hitch, vehicle, robotics, convoy, coupling

A20-095 TITLE: Design and Development of Hardened Autonomy Sensors (Lidar and Radar)

TECHNOLOGY AREA(S): Ground/Sea Vehicles

OBJECTIVE: Provide affordable and reliable high resolution Lidar and/or Radar systems which are hardened to withstand military environments for improved autonomous capabilities.

DESCRIPTION: Autonomous automated vehicles are the next evolution in transportation. Automated vehicles are equipped with multiple sensors (Lidar, radar, camera, etc.) enabling local awareness of their surroundings. A fully automated vehicle will unconditionally rely on its sensors readings to make short-term safety-related and long-term planning driving decisions.

Sensors have to be robust and function under all roadway and environmental conditions. Autonomous vehicles can only work properly with accurate and reliable sensors. They are equipped with a multitude of sensors, using different physical properties (light, ultrasound, radio frequency, etc.), Global Navigation Satellite System and accurate road maps. Lidar and radars are primary sensors used for vehicle automation.

The Army utilizes commercial-off-the-shelf sensors in programs including Expedited Leader Follower, Robotic Combat Vehicle, Autonomous Ground Resupply, and Combat Vehicle Robotics. However, as autonomy is added to tactical and combat platforms, there is a need to harden the sensors to not only withstand military environments such as weather, heavy dust, military shock and vibration, but also gunfire shock. Exposure to a gunfire shock environment has the potential for producing adverse effects on the sensors; potentially reducing or eliminating the platform's autonomous capabilities after just one blast. This SBIR topic would implement design and analysis of hardening Lidar and/or radar under military conditions (hot/cold/humid/shock and vibration/abrasive dust) and conduct laboratory and/or live fire testing.

The following specifications for hardening requirements:
-Water and Dust Sealing: IP69 (the 9 designation is a recent addition to IEC 60529
-Electromagnetic Environmental Effects, per MIL-STD-461 CS101 and RS103.
-Environmental requirements: Operate per MIL-STD-810G, Part Three, Climatic Design Types Cold to Hot, except for a minimum low temperature of -40F.
-Impulse shock and blast over pressure will be provided.

Additional requirements:
Input power per MIL-STD-1275E
Provide a means to clean any external interfaces critical to operation after contaminated with dust, water, or mud.

The Impulse shock and blast over pressure requirements are not derived from a standard; they are based on measured data.
The maximum charge we will use on XM1299A1 will be provided.

PHASE I: Design a proof of concept prototype for an affordable, compact Lidar and/or Radar sensors that meets the specifications outlined in the description. Beyond the desired specs of Lidar and/or Radar sensors operating under military conditions (hot/cold/humid/shock and vibration/abrasive dust), these sensors need to function in a gunfire shock environment. This will provide greater functionality for autonomous system developers and designers. Delivered at the end of this phase will be a white paper outlining the proof of concept design and its feasibility.

PHASE II: The concept prototype will have its design refined and then be developed and built for component level testing. Demonstration and technology evaluation will take place in a relevant laboratory environment or on a military ground vehicle system. Delivered at the end of the phase will be at least 3 units for government feasibility and integration testing.

PHASE III DUAL USE APPLICATIONS: Mechanical packaging and integration of the solution into a vehicle will be achieved (TRL6) and technology transition will occur so the Lidar and/or Radar can be used on military autonomous ground vehicle applications. The Autonomous Ground Resupply Science and Technology Objective (AGR STO) would be a potential entry point for this sensor's application. The hardening of the sensors will also be an attractive feature for the automotive industry as it will provide new avenues towards how they approach autonomous behavior and the harden sensors will provide more reliability.

REFERENCES:
1. http://velodynelidar.com/docs/datasheet/97-0038_Rev%20G_%20HDL-32E_Datasheet_Web.pdf

2. http://everyspec.com

3. https://www.atec.army.mil/publications/Mil-Std-810G/Mil-Std-810G.pdf

4. http://everyspec.com/MIL-STD/MIL-STD-1100-1299/download.php?spec=MIL-STD-1275E.045886.pdf

KEYWORDS: Autonomous, Autonomy Sensors, LIDAR, Radar, Combat Vehicle Robotics

A20-096 TITLE: Sensor suite for Ground Vehicle Survivability

TECHNOLOGY AREA(S): Ground/Sea Vehicles

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 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a Hostile Fire Detection (HFD) and Active Protection System (APS) cueing and tracking sensor suite. Sensors of interest are stationary, non-imaging, multi-aperture combinations for ground vehicle threats.

DESCRIPTION: US Army effectiveness studies demonstrate HFD systems improve vehicle and crew survivability by creating crew situational awareness and cueing defensive systems. HFD systems can detect both Small Arms Fire (SAF) and larger threats like rocket propelled munitions and missiles. HFD systems with real time resolution can provide Army Fighting Vehicles (AFV's) detection, classification, and threat tracking.
High-performance sensors effective against both SAF and larger threats are not fielded on ground vehicle platforms due to their high cost, processing overhead, and integration burden. When employed in research and development APS, HFD/APS cueing systems utilize cameras with cooled Focal Plane Array (FPA) technology for weapons flash detection and projectile tracking. While this approach can be effective, the systems tend to be impractical due to high cost and SWaP-C constraints. In addition, high integration and maintenance burdens limit the potential to field this type of technology on combat and tactical vehicles. Radar systems are not passive devices and can be degraded by clutter in the ground vehicle environment. For SAF detection and localization, lower cost acoustic sensors have been employed but are not effective against larger munitions.
Single modality sensor systems have proved to be prone to environmental clutter, noise, and vibration. Users experience high false alarms under typical operating conditions. Methods involving the use of high sample rate (>10KHz), multi-aperture, uncooled IR detectors have shown to be effective in producing accurate detection, classification and angular location capabilities, but can be prone to environmental clutter, noise and vibration. Multi-aperture sensors potentially offer advantages including low cost, low SWaP-C and complexity, very wide instantaneous field of view, low optical distortion, and a minimal solar exclusion angle. Studies integrating such high-sample rate multi-aperture EO systems with an acoustic modality show significantly reduced SAF False Alarm Rates (FAR) even under high noise/clutter conditions. However, introducing movement to sensors increases clutter to a degree that the fusion engine can be overwhelmed and fail to accurately pair events.
This program seeks to produce a low SWaP-C integrated multi-spectral, multi-aperture, multimodal EO, radar, and acoustic sensor product for ground vehicle survivability. It may be used for sense and warn (HFD) as well as cueing/tracking applications (APS), stationary and on-the-move. It must perform with a high probability of detection and negligible false alarm rate under a variety of challenging conditions and operations. It must also be capable of outputting accurate azimuth (bearing), elevation, and range to target, the target classification, and tracking of the target.
The system must be compliant with the MAPS Architecture Framework (MAF).
This topic will address a threat list to include: SAF (e.g. 5.56, 7.62, .50 Caliber), cannons (e.g. turreted, mortar), Rocket Propelled Grenades (RPGs), Recoilless Rifles, and Anti-Tank Guided Missiles (ATGMs).

PHASE I: Investigate and identify materials, packaging, design methodologies and critical design parameters for an HFD/APS cueing and tracking sensor system consisting of a high speed, multi-aperture, multi-spectral sensors for use in on-the-move environments. Analyze and model the far field performance of the proposed sensor where far field is proposed by the contractor and should represent a militarily useful distance. Build and test breadboards to prove high risk design element feasibility. Begin design of a prototype system that achieves the requirements and capabilities. Deliverables include final report detailing design process, Preliminary Design Review, documentation, and supporting data.

PHASE II: Finalize the initial design from Phase I. Build a proof-of-concept prototype system that will be used for hardware-in-the-loop testing and evaluation. Prototype must be MAF compliant. Perform initial testing and system characterization including testing of the design limits based on the modeling and analysis in Phase I. Identify areas to explore for a finalized system design and technical/programmatic risks. Deliverables include Critical Design Review and documentation, prototype hardware that will be used in government lab and field data collections.

PHASE III DUAL USE APPLICATIONS: Fabricate and deliver final test article. Support live fire testing, analysis and system upgrades as required. Further mature the technology, preparing for technology insertion into existing programs of record with the transition partner, PdM Vehicle Protection Systems. Deliverables include finalized prototype design documentation, manuals and hardware, including software. A potential commercial application of this project is for autonomous driving vehicles. Mass market autonomous vehicles require multiple, overlapping sensors with many of the same restrictions as military vehicles: clutter, safety, and cost.

REFERENCES:

1. Michael V. Scanlon and William D. Ludwig "Sensor and information fusion for improved hostile fire situational awareness", Proc. SPIE 7693, Unattended Ground, Sea, and Air Sensor Technologies and Applications XII, 76930H (19 May 2010); doi: 10.1117/12.850406; https://doi.org/10.1117/12.850406

2. Gil A. Tidhar, Ori B. Aphek, and Eliyahu Cohen "OTHELLO: a novel SWIR dual-band detection system and its applications", Proc. SPIE 8704, Infrared Technology and Applications XXXIX, 87040E (11 June 2013); doi: 10.1117/12.2019202; https://doi.org/10.1117/12.2019202

3. Davis, Jami et al "Challenges of Ground-Based Hostile Fire Detection and Location", US Army RDECOM CERDEC NVESD Technical Report, 8 September 2014; DTIC Accession Number: SENSIAC-2083014; https://www.dtic.mil/DTIConline/downloadPdf.search?collectionId=tems&docId=SENSIAC-2083014

4. Pauli, Myron et al, "Fusion of Passive Flash Detection with Cued Active Pulsed-Doppler Tracking for Bullets, Rocket Propelled Grenades, and Missiles, NRL, US Army CERDEC I2WD, DOT&E Center for Countermeasures (WSMR), Lucid Dimensions, and Meggitt Defense Systems; 27 February 2012; Accession Number: SENSIAC-1991771; https://www.dtic.mil/DTIConline/downloadPdf.search?collectionId=tems&docId=SENSIAC-1991771

5. Brown, Jeremy et al, "Clutter Mitigation for Ground Vehicle Hostile Fire Detection and Location (HFDL) Using EOIR Sensors", US Army CERDEC NVESD, 14 September 2015; Accession Number: SENSIAC-2090976; https://www.dtic.mil/DTIConline/downloadPdf.search?collectionId=tems&docId=SENSIAC-2090976

KEYWORDS: Survivability, ground vehicle survivability, Active Protection System sensors, Hostile Fire Detection, multi-function sensors, multi-spectral sensors

A20-097 TITLE: Engineered Synthetic Replacement for Army Heavy Transport Trailer Wooden Decking and Flooring.

TECHNOLOGY AREA(S): Ground/Sea Vehicles

OBJECTIVE: A robust physical configuration and manufacturing source for engineered synthetic floor boards (aka. decking) for Army Heavy Trailers, as well as any trailer that uses wood planking for deck-boards.

DESCRIPTION: Currently, Army heavy trailers primarily use the critically endangered rain-forest wood apitong. Problem to be solved is the frequent and costly redecking of Army heavy trailers.

Decking is an often overlooked integrated structural element of Tactical Trailers. Worldwide, approximately 16,500 DoD military trailers (in both production & sustainment) are decked nearly exclusively in $65M of Apitong, which is an increasingly rare and critically endangered East-Asian tropical rainforest hardwood (i.e. price is rising). Apitong is the only known endangered species actively harvested from nature for DoD use. Apitong has a field service life of only 8 years due to its susceptibility to rot and insect attack, requiring replacement up to 5 times over a 40 year lifecycle, resulting in wasteful utilization of a foreign endangered resource, downtime in addition to 'random' board replacement as damage occurs in addition to soldier labor time and incidentals such as corrosion repair and spot painting. An estimated lifecycle cost of $15K to $25K per trailer (in today's dollars @ $5K each in material and labor to re-deck every 8 to 10 years, leading to a life-cycle potential cost-avoidance for all trailers of >$400 million).

Performance Requirements:

- Sustained load-bearing of payload (5400 lb/ft2 est. for contact patch 7,500 lb / 200 in sq.) on 24" spaced crossmembers (3" top flange) without permanent deformation. Inherent stiffness shall not allow sag (deflection) under load of more than 1/4" between crossmembers. Ref Drawing 12624740 M871A3 Semitrailer Floor Boards.
- Equal or greater mechanical properties vs Apitong/Keruing. Ref. A-A-52520.
- Resistant to standard automotive fluids including JP-8 and similar diesels, MoGas, motor oil, trans, brake

and hydraulic fluid, gear lube, battery acid and caustics. Resist weathering – solar: UV and ozone, thermal -40 to +130F. Ref MIL-STD-810.

- Anti-mold & fungal growth inhibitors such as MicroBan ® or BioBlock ® shall be incorporated. Insect immune – example worst case Formosan termite infestation.
- Fastener req'ts and corrosion cause/isolation req'ts shall be selected for service life longevity.
- Saw and drill using standard wood working tools.
- Able to drive nails into and remove with minimal damage, holes reparable with caulk. Alternative std. fasteners may be acceptable.
- Maintenance-free except for repair of incidental damage.
- Fire-resistant, self-ext. 'UL94-HB'/MIL-PRF-32518.
- Desired service life: 25 years or longer, with minimal maintenance (life of trailer).
- Color shall be a deep brown to a weathered gray.
- Successful product will supersede all wood decking across all trailers fleet-wide, and exhibit a service life-longevity of up to the life of the trailer; potentially having a cost avoidance of millions of dollars.

PHASE I: Evaluate multi-disciplinary 'states-of-the-art' and develop a detailed plan for composite, metal, polymeric or hybrid material trailer flooring board prototype for fabrication and testing in a relevant environment. Prior (market) research (TACOM Study – 2000) found no suitable commercially available products – use this study for a baseline. Use modeling to determine loads to be borne –MRAP Buffalo, M-113 as payloads. Buffalo front wheel is heaviest-case: 7,500 lbs over 200 in2 = 5400 lb/ft2. Determine design feasibility of concept. Explore other load situations such as impact and rock/gravel rollover.

PHASE II: Design a demonstrator configuration for the M-871A3 22.5 ton trailer, fabricate representative samples of candidate materiel configurations and conduct testing. Testing shall include at a minimum: static load, fatigue loading, accelerated weathering, surface coefficient of friction, simulate damage tolerance to include nailing of cribbing, hammer strikes, rock/gravel roll-overs, fluid immunity (MoGas, diesel, other vehicular fluids and caustics) and fire resistance. Best performer(s) shall be selected for demonstration project: Deliverable will be approx. 1000 linear feet, to redeck six M870A3 heavy trailers for testing.

PHASE III DUAL USE APPLICATIONS: Commercialization shall entail full rate production of the selected configuration. Potential Phase III military applications include M871A3 trailer (Ref. TACOM Drawing 126247025 22.5 ton); also include M872A3 & A4 34 ton and M172 22 ton. Commercial equivalent trailers of any uncovered size from tandem axle 10 ton for a backhoe to a 50 ton multi-axle lowboys for the oversize excavators and off-road dump trucks. Covered semi-trailers are also included, with reduced flooring thickness.

REFERENCES:
1. DTIC Publication "Trailer Decking Technology Study" Trailer Research and Development Contract No. DAAE07-99-C-S016, November 30, 2000

2. TACOM Drawing 12624740 M871A3 Semitrailer Floor Boards

3. CID A-A-52520 Hardwood: Floorboards and Platforms: For Military Vehicles (Metric)

4. MIL-STD-810 Military Test Methods: Environmental Engineering Considerations

5. MIL-PRF-32518 Interior Vehicle Human Factors Including Smoke and Toxicity

KEYWORDS: Composite, Wood, Decking, Flooring, Trailer

A20-098 TITLE: Energy Attenuation Bench Seat System

TECHNOLOGY AREA(S): Ground/Sea Vehicles

OBJECTIVE: The Energy Attenuation Bench Seat System will protect and accommodate multiple sized Soldiers from a variety of typically injurious scenarios like Vehicle Borne Improvised Explosive Devices (VBIED), underbody blast, top/bottom attacks, crash, and rollover events. By consolidating seating to benches and reducing the overall footprint of the seat, vehicle length could be reduced achieving a significant overall weight savings.

DESCRIPTION: Ground vehicle energy attenuating seat systems are traditionally designed to accommodate and protect a single Soldier with a prescribed distance between seats. Limited existing Military bench seating does not provide energy attenuation, desired accommodation, or an adequate level of Soldier endurance and performance. A new bench seating system shall be internally mounted in the vehicle with integrated restraint systems, and either provide or account for integrated or under-seat storage. The seat shall accommodate 4 fully encumbered occupants of varying size within the central 90th percentile and protect them during events including, but not limited to: underbody blast, crash, rollover, Top/Bottom attack, and VBIED. The bench seat shall be able to protect varying combinations of occupant sizes ranging from a single 5th percentile female up to four 95th percentile males, and allow for a minimum of 26" from centerline to centerline of each occupant.

PHASE I: Define and determine the technical feasibility of developing an energy attenuation bench seat system that is lightweight, durable, and can protect the occupants from high energy inputs. The seat must protect and accommodate the central 90th percentile Soldier population while fully encumbered and be lightweight and durable enough to handle the rugged conditions encountered by ground vehicles. Seats must be FMVSS 207/210 compliant. The seat must, at a minimum, meet FMVSS 208 Injury Criteria (additional Injury Criteria will be provided once on contract) for the following tests: drop tower testing (up to 350g half sine pulse, delta V 10 m/s), and FMVSS 213 Child Seat Corridor Sled Testing.

PHASE II: Develop and test at least 5 prototype seat systems that can protect and accommodate the Soldiers during high energy events including, but not limited to: blast, crash, rollover, and VBIED. Based on the findings in Phase I, refine the concept, develop a detailed design, and fabricate a simple prototype system for proof of concept. Identify steps necessary for fully developing a commercially viable seat system. Seats must be FMVSS 207/210 compliant. The seat must, at a minimum, meet FMVSS 208 Injury Criteria (additional Injury Criteria will be provided once on contract) for the following tests: drop tower testing (up to 350g half sine pulse, delta V 10 m/s), and FMVSS 213 Child Seat Corridor Sled Testing.

PHASE III DUAL USE APPLICATIONS: Commercialization to Stryker (PM-SBCT), with potential integration in Next Generation Combat Vehicles (NGCV). Potential additional military applications include, but are not limited to other Combat Vehicles.

REFERENCES:

1. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA608804

2. www.arl.army.mil/arlreports/2007/ARL-TR-4236.pdf

3. http://armypubs.army.mil/doctrine/DR_pubs/dr_a/pdf/atp4_25x13.pdf

KEYWORDS: Energy attenuation, seats, bench, underbody blast, crash, rollover, vehicle borne improvised explosive device (VBIED), top/bottom attack, mitigate energy, accommodate and protect, central 90th percentile Soldier population

A20-099 TITLE: Secure FPGA Zeroization for Military Systems Abandonment

TECHNOLOGY AREA(S): Ground/Sea Vehicles

OBJECTIVE: Use reconfigurable logic hardware to create general purpose, secure circuitry with zeroize functionality for military systems abandonment in theater. This ensures that the enemy cannot reverse engineer US military systems, while also reducing microelectronics development costs.

DESCRIPTION: Current Army ground vehicle systems operate using Application Specific Integrated Circuits (ASIC), due to Size, Weight, AP-C requirements. One could move to implement designs on a reprogrammable logic board such as a Field Programmable Gate Array, with a System on a Chip (SOC) acting as the design synthesis (programming) tool host on the printed circuit board. The FPGA fabric can be used to implement the functionality that would normally be hosted using an ASIC. FPGAs, by nature (unless using an anti-fuse FPGA design), are reprogrammable. Recent advancements by the major FPGA manufacturers, Altera (Intel) & Xilinx, have brought FPGA systems much closer to the SWAP-C that ASICs operate at. These recent advancements have also brought FPGA encryption and hardening to the level that was required with ASIC designs, making it a valid platform for military systems.

Currently, efforts are only made to harden those electronics that are deemed Critical Program Information (CPI) so that they are either time-impossible, or extremely high effort to reverse engineer. However, non-CPI electronics do not receive the same hardware resiliency, and thus are still at risk of exploitation if captured. If the warfighter must abandon a vehicle in theater, valuable electronics may be attached to that ground vehicle that should be destroyed. Current standard, operating destruction procedures in require the use of pyrotechnics (thermite grenades), which can fail to completely destroy the ASIC hardware. That leaves the enemy with hardware that could be reverse engineered off the intact portion.

By hosting the design on a reprogrammable device, one can achieve the same or near-same level of SWAP-C as would be hosted by an ASIC, but have a reprogrammable design fabric to work with. Using the SOC on the device, hosting a light embedded OS with scripts to execute zero-ization at the touch of a button, one could use the design to create a kill-switch. By rewriting the fabric with a blank design, one would effectively delete the existing logic, thus making it nearly impossible to exploit the hardware. This means that the design would be tamper resistant.

A key example of where this proposed technology would have been extremely useful in was in the year 2001, where China had ‘captured’ a damaged EP-3E spy plane that had to make an emergency landing on Hainan Island Chinese military base. China had ample time to reverse engineer any of the electronics systems onboard that airplane, before returning it back to the USA, partially dismantled.

As such, any hardware ASIC design that can be ported to reprogrammable logic would be the target for this proposal, making upcoming platforms such as the NGCV far more cyber-resilient. And if shown to work, could be something applicable to all DOD agencies and OGAs. The US Army is seeking proposed designs and guidance on how such a re-synthesizable design might be implemented.

PHASE I: Offeror shall conduct a feasibility study through research on whether current general purpose FPGA boards and design logic can be adapted to this design. This study shall include viability and potential applications, not covered by this topic, for military, medical, and commercial implementations.

PHASE II: Depending on the results of the Phase I feasibility study, the Offeror shall implement the logic design of a system from a military ground vehicle on an FPGA platform (i.e. Altera or Xilinx) to show a proof of concept prototype.

Offeror will propose the system architecture that is to be used (hardware, software, etc.). Offeror will create design logic for an FPGA using respective FPGA environments. This logic will implement a systems design that meets military data encryption standards. Offeror shall also create software that can synthesize the FPGA logic with a zeroized design if given a command to do so. This software shall be able to interface with a user interfacing system (hardware).

At the end of Phase II, Offeror shall have a working prototype of this system with a Technology Readiness Level of at minimum, TRL6. Offeror shall also have a business model ready for marketing the proposed system to commercial vendors.

PHASE III DUAL USE APPLICATIONS: Offeror will develop systems that can be retrofit with current military ground vehicles. This will provide the US military with capabilities of protecting government and our contractor’s intellectual property during wartime. It will also prevent enemies from reverse engineering our hardware and using our own designs to harm our warfighters, Additionally, this design can see commercial viability by allowing for companies to protect their trade secrets and intellectual property, either from competitors, foreign nations, or malicious actors.

REFERENCES:
1. "Understanding Zeroization To Clear System Data For FIPS-Approvedmode Of Operation - Technical Documentation - Support - Juniper Networks". Juniper.Net, 2016, https://www.juniper.net/documentation/en_US/junos-fips12.1/topics/concept/understanding-zeroization.html. Accessed 14 May 2019.

2. IBM. Building A High-Performance, Programmable Secure Coprocessor. Princeton, IBM T.J. Watson Research Center, Yorktown Heights, New York, 1998, pp. 1-38, https://www.princeton.edu/~rblee/ELE572Papers/building_hp_secop.pdf.

3. Zeroization. Microsemi Corporation, 2012, pp. 1-8, https://www.microsemi.com/document-portal/doc_download/129972-ac382-zeroization-app-note.

KEYWORDS: Reconfigurable , Logic , Zeroize , Organic , Circuit , FPGA , System on a Chip , SOC , tamper , Electronics , Microelectronics , Zeroization

A20-100 TITLE: Reconfigurable Computer Architecture for Flexible Input / Output (I/O)

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop a reconfigurable computing-based platform that provides reprogrammable hardware implementations for multiple communication protocols, cryptographic algorithms, and heterogeneous architectures for ground vehicle sensor/system integration (e.g. signal concentration for routing through Next Generation Combat Vehicle slip ring), hardware accelerated capability insertion, and mitigation of semiconductor device obsolescence.

DESCRIPTION: The Army has long been interested in leveraging the benefits of Field Programmable Gate Array (FPGA) and System on Chip (SoC) technologies to mitigate performance and obsolescence issues associated with the extended life cycle of Army weapon systems. Historically the Army spends over a decade to design, test, and field a new weapon system and this means that, in many cases, the computing hardware and communication technology is obsolete by the time it is fielded [1]. To decrease this impact of this, weapon system functionality can often be migrated to software but this can be detrimental when the software implementation incurs a significant performance penalty or when the software cannot be written portably, resulting in code that is tightly coupled to a specific microprocessor or microcontroller; this is especially true when the software performs safety-critical functions, needs to perform deterministically and targets a specific instruction set architecture (ISA). Incorporation of FPGA technology has traditionally been recognized as one way to protect against electronics obsolescence while preserving the ability to implement performance upgrades [2]. High-level synthesis languages and semiconductor intellectual property (IP) cores have matured to the degree that it may be possible for the Army to leverage them on a computing platform which can incorporate open-source soft-core processors (e.g. RISC-V) to mitigate software obsolescence [3], readily instantiate new circuitry via logic synthesis to support emerging capabilities (e.g. artificial neural networks), and also provide a path for updating to different communication technologies primarily through logic synthesis (e.g. migration of 1 Gigabit Ethernet to 10 Gigabit Ethernet). This topic seeks innovative approaches to leverage reconfigurable computing and FPGA technology to increase the flexibility, longevity, capabilities, and performance of computing platforms within Army ground vehicles, specifically used to implement emerging capabilities on a Bradley and/or Optionally-Manned Fighting Vehicle (OMFV), to process multiple types of I/O and is reconfigurable to evolve along with vehicle programs and technology. A highly competitive solution should, with minimal changes to the electronics, provide reconfigurable: (1) hardware acceleration for running selectable cryptographic algorithms (e.g. Secure Hash Algorithm [SHA]-256, SHA-512, Advanced Encryption Standard [AES]-128, AES-256) (2) hardware-supported video processing and distribution (3) heterogeneous architecture to support simultaneous hosting of real-time, safety-critical and general purpose Linux software (4) support for multiple channels of serial communication (e.g. RS-422, RS-232, Controller Area Network [CAN], Inter Integrated Circuit [I2C]) (5) support for multiple channels of Ethernet (e.g. Gigabit Ethernet [GbE], 10 GbE, Audio-Video Bridging [AVB]/ Time Sensitive Networking [TSN]) (6) support for multiple types of analog and discrete signals (e.g. audio, RS-170) (7) Provides an Interface Configuration Document (ICD), hardware performance specification, and Technology Readiness Level (TRL) 6 test report.

PHASE I: Investigate the design space for reconfigurable computing based, ruggedized platforms. Define metrics for assessing obsolescence risk reduction and re-configurability, as well as difficulty/cost associated with using reconfigurable computing technology, IP cores, hardware, and tools. Develop initial reference designs to illustrate I/O processing/conversions, communications/cryptographic migration, and heterogeneous computing scenarios.

PHASE II: Fully develop the technology and demonstrate general features of the Flexible I/O platform, which consists of hardware, firmware, software, and synthesizable logic in the form of hardware description language (HDL) or IP cores. Evaluate using the metrics defines in Phase I. Execute selected computing/migration scenarios and collect metrics as defined in Phase I. Perform additional testing to assess performance and operational impacts and provide an ICD and hardware performance specification.

PHASE III DUAL USE APPLICATIONS: Phase III applications include deploying Flexible I/O platform in the Bradley or OMFV vehicle for processing/distribution of 3rd Gen FLIR video information and signal compression/decompression for transmission through slip-ring. Phase III potential applications include the use of Flexible I/O for long-life span, advanced Internet-of-Things (IoT), Industrial Control System (ICS), medical imaging devices, or autonomous systems.

REFERENCES:
1. Research and Technology Organization, “Strategies to Mitigate Obsolescence in Defense Systems Using Commercial Components”, DTIC https://apps.dtic.mil/dtic/tr/fulltext/u2/a394911.pdf June 2001

2. R. Dupree, “Determination of the Timeline for U.S. Army Aviation Systems to Reach Operational Obsolescence Following Termination of Modernization Funding”, DTIC https://apps.dtic.mil/dtic/tr/fulltext/u2/a417438.pdf June 2003

3. G. Peckham, “Programmable Logic Holds the Key to Addressing Device Obsolescence” Electronic Engineering Times https://www.eetimes.com/author.asp?section_id=36&doc_id=1332754 December 2017

KEYWORDS: FPGA, Softcore Processor, Heterogeneous Computing, Reconfigurable Computing, IP Cores, Obsolescence