The approved 20.B Broad Agency Announcement (BAA) topics for the Army Small Business Technology Transfer (STTR) Program are listed below. Offerors responding to this BAA must follow all general instructions provided in the Department of Defense (DoD) Program BAA. Specific Army STTR requirements that add to or deviate from the DoD Program BAA instructions are provided below with references to the appropriate section of the DoD BAA.

The STTR Program Management Office (PMO), located at the Combat Capabilities Development Command (CCDC) Army Research Laboratory (ARL) Army Research Office (ARO), manages the Army’s STTR Program. The Army STTR Program aims to stimulate a partnership of ideas and technologies between innovative small business concerns (SBCs) and research institutions (RIs) through Federally-funded research or research and development (R/R&D). To address Army needs and opportunities, the PMO relies on the vision and insight of science and engineering workforce across nine (9) participating Army organizations to put forward topics that are consistent with their mission, as well as command and STTR program goals. More information about the Army STTR Program can be found at https://www.armysbir.army.mil/sttr/Default.aspx.

See DoD Program Announcement Section 4.15 for Technical questions and Topic Author communications. Specific questions pertaining to the Army STTR Program should be submitted to:

Army STTR Program Manager
usarmy.rtp.aro.mail.sttr-pmo@mail.mil

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

**PHASE I PROPOSAL GUIDELINES**

Phase I proposals should address the feasibility of a solution to the topic. The Army anticipates funding two (2) STTR Phase I contracts to small businesses with their research institution partner for each topic. The Army reserves the right to not fund a topic if the proposals received have insufficient merit. Phase I contracts are limited to a maximum of $166,500 over a period not to exceed six (6) months. **PLEASE NOTE THAT THE MAXIMUM DOLLAR AMOUNT HAS BEEN INCREASED COMPARED TO PREVIOUS PHASE I’s.** Army STTR uses only government employee reviewers in a two-tiered review process unless otherwise noted within the topic write-up. Awards will be made on the basis of technical evaluations using the criteria described in this DoD BAA (see section 6.0) and availability of Army STTR funds.

The DoD SBIR/STTR Proposal Submission system (https://www.dodsbirsttr.mil/submissions/login) provides instruction and a tutorial for preparation and submission of your proposal. Refer to section 5.0 at the front of this BAA for detailed instructions on Phase I proposal format. You must include a Company Commercialization Report (CCR) as part of each proposal you submit. If you have not updated your commercialization information in the past year, or need to review a copy of your report, visit the DoD SBIR/STTR Proposal Submission site. Please note that improper handling of the CCR may have a direct impact on the review and evaluation of the proposal (refer to section 4.16 of the DoD BAA).

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 for 18.B Phase I proposals. The Army has established a 10-page limitation for Technical Volumes submitted in response to its topics. This does not include the Proposal Cover Sheets (pages 1 and 2, added electronically by the DoD submission site), the Cost Volume, or the CCR. The Technical Volume includes, but is not limited to: table of contents, pages left blank, references and letters of support, appendices, key personnel biographical information, and all attachments. The Army requires that small businesses complete the Cost Volume form on the DoD Submission site versus submitting it within the body of the uploaded Technical Volume. It is the responsibility of submitters to ensure that the Technical Volume portion of the proposal does not exceed the 10-page limit. Do not include blank pages, duplicate the electronically generated cover pages or put information normally associated with the Technical Volume such as descriptions of capability or intent in other sections of the proposal as these will count toward the 10-page limit. Army STTR Phase I proposals submitted containing a Technical Volume over 10 pages will be deemed NON-COMPLIANT and will not be evaluated. It is the responsibility of the Small Business to ensure that once the proposal is submitted and uploaded into the system that the technical volume.pdf document complies with the 10 page limit. If you experience problems uploading a proposal, call the DoD SBIR/STTR Help Desk at 703-214-1333 (9:00 am to 5:00 pm ET Monday - Friday).

Proposals not conforming to the terms of this BAA will not be considered. Only Government personnel will evaluate proposals with the exception of technical personnel from ICON who will provide Advisory and Assistance Services to the Army and technical analysis in the evaluation of proposals submitted against Army topic number:

- A20B-T023 Develop and Demonstrate a Portable Device for Bacteriophage Enrichment, Screening and Isolation Technology for Field Application

The individuals from ICON will be authorized access to only those portions of the proposal data and discussions that are necessary to enable them to perform their respective duties. These institutions are expressly prohibited from competing for STTR awards and from scoring or ranking of proposals or recommending the selection of a source. In accomplishing their duties related to the selection processes, the aforementioned institutions may require access to proprietary information contained in the offerors’ proposals. Therefore, pursuant to FAR 9.505-4, the institution must execute an agreement that states that they will (1) protect the offerors’ information from unauthorized use or disclosure for as long as it remains proprietary and (2) refrain from using the information for any purpose other than that for which it was furnished. These agreements will remain on file with the Army STTR program management office at the address above.

Companies should plan carefully for research involving animal or human subjects, biological agents, etc. (see sections 4.7 - 4.9). The short duration of a Phase I effort may preclude plans including these elements unless coordinated before a contract is awarded.

If the offeror proposes to employ a foreign national, refer to sections 3.5 and 5.4.c (8) in the DoD BAA for definitions and reporting requirements. Please ensure no Privacy Act information is included in this submittal.

If a small business concern is selected for an STTR award, they must negotiate a written agreement between the small business and their selected research institution that allocates intellectual property rights and rights to carry out follow-on research, development, or commercialization (section 10).
PHASE II PROPOSAL GUIDELINES

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

Phase II proposals will be evaluated for overall merit based upon the criteria in section 8.0 of this BAA. STTR Phase II proposals have four Volumes: Proposal Cover Sheet, Technical Volume, Cost Volume and Company Commercialization Report. The Army STTR Program does not accept submission of Volume Five, Supporting Documents, nor a Volume Six (Fraud, Waste and Abuse) as noted at the DoD SBIR website for 18.B Phase II proposals. The Technical Volume has a 20-page limit including: table of contents, pages intentionally left blank, technical references, letters of support, appendices, technical portions of subcontract documents (e.g., statements of work and resumes) and any attachments. However, offerors are instructed to NOT leave blank pages, duplicate the electronically generated cover pages or put information normally associated with the Technical Volume in others sections of the proposal submission as these will count toward the 20-page limit. ONLY the electronically generated Cover Sheets, Cost Volume and CCR are excluded from the 20-page limit. As instructed in section 5.4.e of the DoD Program BAA, the CCR is generated by the submission website based on information provided by you through the “Company Commercialization Report” tool. Army STTR Phase II proposals submitted containing a Technical Volume over 20 pages will be deemed NON-COMPLIANT and will not be evaluated.

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

Army Phase II Cost Volumes must contain a budget for the entire 24-month period not to exceed the maximum dollar amount of $1,100,000. PLEASE NOTE THAT THE MAXIMUM DOLLAR AMOUNT HAS BEEN INCREASED COMPARED TO PREVIOUS PHASE II’s) Costs for each year of effort must be submitted using the Cost Volume format (accessible electronically on the DoD submission site). The total proposed amount should be indicated on the Proposal Cover Sheet as the Proposed Cost. Phase II projects will be evaluated after the base year prior to extending funding for the option year. Phase II proposals are generally structured as follows: the first 10-12 months (base effort) should be approximately $550,000; the second 10-12 months of funding should also be approximately $550,000. The entire Phase II effort should not exceed $1,100,000. The Phase II contract structure is at the discretion of the Army’s Contracting Officer, and the PMO reserves the option to reduce an annual budget request of greater than $550,000 if program funds are limited.

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

In accordance with section 9(q) of the Small Business Act (15 U.S.C. 638(q)), the Army will provide technical assistance services to small businesses engaged in STTR projects through a network of scientists and engineers engaged in a wide range of technologies. The objective of this effort is to increase Army STTR technology transition and commercialization success thereby accelerating the fielding of capabilities to Soldiers and to benefit the nation through stimulated technological innovation, improved manufacturing capability, and increased competition, productivity, and economic growth.

The Army has stationed nine (9) Technical Assistance Advocates (TAAs) across the Army to provide technical assistance to small businesses that have Phase I and Phase II projects with the participating Army organizations within their regions. Details related to TABA are described in section 4.22 of the DoD BAA. Firms may request technical assistance from sources other than those provided by the Army. All such requests must be made in accordance with the instructions in Section 4.22. It should also be noted that if approved for TABA from an outside source, the firm will not be eligible for the Army’s TAA support. 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 STTR Program Manager.

For more information go to: https://www.armysbir.army.mil/sbir/TechnicalAssistance.aspx

NOTIFICATION SCHEDULE OF PROPOSAL STATUS AND DEBRIEFS

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

PROTEST PROCEDURES

Refer to the DoD Program Announcement for procedures to protest the Announcement.

As further prescribed in FAR 33.106(b), FAR 52.233-3, Protests after Award should be submitted to: usarmy.rtp.aro.mail.strr-pmo@mail.mil

DEPARTMENT OF THE ARMY PROPOSAL CHECKLIST

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

1. The proposal addresses a Phase I effort (up to $166,500 for up to six-month duration).
2. The proposal is addressing only **ONE** Army BAA topic.

3. The technical content of the proposal includes the items identified in section 5.4 of the BAA.


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

6. 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 – see website at [https://www.ecmra.mil/](https://www.ecmra.mil/).

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

8. If applicable, include a 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 STTR project from research to an operational capability that satisfies one or more Army operational or technical requirement in a new or existing system, larger research program, or as a stand-alone product or service.

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

**ARMY STTR PROGRAM COORDINATORS (PCs) and Army STTR 20.B Topic Index**

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<tbody>
<tr>
<td>CCDC-Armaments Center</td>
<td>Benjamin Call</td>
<td>973-724-6275</td>
</tr>
<tr>
<td></td>
<td>Sheila Speroni</td>
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</tr>
<tr>
<td>CCDC-Aviation and Missile Center</td>
<td>Dawn Gratz</td>
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</tr>
<tr>
<td>CCDC-ARL/Army Research Office</td>
<td>Nicole Fox</td>
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</tr>
<tr>
<td>CCDC-C5ISR Center</td>
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</tr>
<tr>
<td>CCDC-Chemical Biological Center</td>
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</tr>
<tr>
<td>CoE-Environmental Research and Development Center (ERDC)</td>
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</tr>
<tr>
<td>Medical Research and Development Command (MRDC)</td>
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<tr>
<td></td>
<td>Amanda Cecil</td>
<td>301-619-7296</td>
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<tr>
<td>CCDC-Soldier Center</td>
<td>Cathy Polito</td>
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<tr>
<td>CCDC-Ground Vehicle Systems Center</td>
<td>George Pappageorge</td>
<td>586-282-4915</td>
</tr>
<tr>
<td></td>
<td>Joseph Delfrate</td>
<td>586-282-5568</td>
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ARMY

ARMY SBIR 20.B Topic Index

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A20B-T007 Actuation for human-scale dynamic whole-body manipulation
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A20B-T009 Three-Dimensional Microfabricated ion Traps for Quantum Sensing and Information Processing
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A20B-T001	TITLE: Implementation of Hierarchical Phase Change Materials for Applications in Long Range Precision Fires Missions

RT&L FOCUS AREA(S): 5G, General Warfighting Requirements
TECHNOLOGY AREA(S): Materials

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: This topic shall investigate hierarchical phase change materials that can be used for the enhancement of thermal, mechanical, and/or electromagnetic properties.

DESCRIPTION: Long Range Precision Fires (LRPF) as one of the Army Modernization Priorities seeks to develop technologies that increase weapon system range. Projectiles fitting this new paradigm must survive high-g and high-temperature environments; therefore, novel materials with enhanced thermal and mechanical properties are required to meet these emerging needs. Phase Change Materials (PCM) can address these issues by undergoing structural or phase transformations, thus allowing for the absorption of heat or mechanical stress; indeed such materials have been implemented in applications for such a purpose [1, 2]. Typical solid-liquid PCM suffer from several disadvantages [3]; therefore, other approaches such as solid-solid phase transitions and strongly correlated electron systems are attractive due to the reversible nature of their phase transitions [4, 5]. In order to ensure the survivability of internal components under the aforementioned extreme conditions, novel material design approaches are required to enable novel and/or passive coatings for LRPF platforms. To this end, this topic seeks novel solutions exploiting the phase change properties of materials in order to provide platform protection against a broad range of extreme environmental threats that are unique to the LRPF mission.

PHASE I: Phase I will focus on designing hierarchical PCM that can be synthesized and implemented as passive/active coatings or structural elements to enhance the survivability of LRPF platforms against extreme environments. The design should be informed by fundamental studies of a broad materials library that includes but is not limited to: nanostructured inorganic, organic, and/or hybrid inorganic/organic composites including low dimensional materials. The combination of physical approaches and novel nanomaterials should enable properties such as high heat capacity, thermal conductivity and mechanical strength; electromagnetic properties shall also be considered. Phase I will result in design methods, modeling and simulation analyses and material trade-off considerations for achieving the objectives. Prototype material structures will be synthesized to demonstrate the desired properties and identify the potential for implementation on LRPF platforms.
PHASE II: Modeling and simulation will be utilized to elucidate the physics behind the novel materials’ properties which enable survivability against a range of extreme conditions including high-g and high temperature. The expected technology development work will include detailed investigations into the desired materials and their properties and performance in the desired application in the context of user requirements in conjunction with the Army; strong consideration will be given to the reliability and robustness in the context of real-world LRPF platforms. The successful phase II will deliver prototype material systems to the Army for testing in various extreme environments as well as independent characterization of the material properties.

PHASE III DUAL USE APPLICATIONS: Modeling and simulation will be utilized to elucidate the physics behind the novel materials’ properties which enable survivability against a range of extreme conditions including high-g and high temperature. The expected technology development work will include detailed investigations into the desired materials and their properties and performance in the desired application in the context of user requirements in conjunction with the Army; strong consideration will be given to the reliability and robustness in the context of real-world LRPF platforms. The successful phase II will deliver prototype material systems to the Army for testing in various extreme environments as well as independent characterization of the material properties.

REFERENCES:
1. Ling, Ziye et al. “A hybrid thermal management system for lithium ion batteries combining phase change materials with forced-air cooling”. Applied Energy. 2015.;
5. Muramoto, Kei et al. “VO2-dispersed glass: A new class of phase change material”. Scientific Reports. 2018. DOI:10.1038/s41598-018-20519-6

KEYWORDS: Long Range Precision Fires, hierarchical materials, phase change materials, long range, extended range, nanomaterials, low-dimensional materials

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Phone: 973-724-8374
Email: aaron.m.stern3.civ@mail.mil
A20B-T002  TITLE: A Revolutionary RF Circuit Simulator for New Electronic Design and Analysis Capabilities

RT&L FOCUS AREA(S): 5G
TECHNOLOGY AREA(S): Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop trusted computer simulation software to accurately and quickly analyze the end-to-end circuit behavior of completely general time-frequency waveforms in complex non-linear RF circuitry.

DESCRIPTION: Anecdotally, a dozen fabrication cycles, 1000 or more engineers, and billions of dollars were required to develop the prototype for a modern cellular modem. Current commercially available circuit simulation software is not capable of fast, accurate analysis of the response of an entire complex linear and non-linear circuit to modern time-frequency waveforms. RF circuits are currently designed based on intuition derived from the analysis of many summations of steady-state functions such as sine waves or the transient analysis of circuit response with relatively small dynamic range. RF circuits tend to be designed starting from a steady-state analytical solution, followed by extensive trial and error fabrications. Small parts of the circuit are simulated for short time intervals and the results are combined based on engineering intuition. However components of RF circuits can respond in unexpected modes when subjected to wave forms which have formulations in both time and frequency. A simple example is pulses of sinusoidal waves. The response of filters and in particular non-linear circuit elements to these time-frequency waveforms can be substantially different than would be expected from a steady state wave form analysis. Even relatively simple 5G waveforms such as OFDM and CDMA modulation can be hard to accurately analyze. More general time-frequency waveforms where the frequency content varies with time and RF transients can dominate the response may be of interest for jamming and EW or the construction of LPI waveforms. Circuit simulation tools commercially available do not have the dynamic range to address these waveforms, the number of state variables required can grow exponentially, and computation time can take weeks for a single circuit for even a limited circuit time period under analysis. These simulation tools can have dynamic ranges on the order of 80 dB, while a dynamic range above 140 dB may be required, as well as the capability to reduce the number of state variables. An appropriate simulation will also require the capability to handle true time delay and memory effects in a physically correct manner. Macro-models will be needed to address these performance and computational speed requirements. These can include accurate behavioral
models and reduced-order models. Fractional calculus and complex basis functions such as wavelets may be useful in constructing these macro-models. The software should be capable of simulating the 5G waveform response in a generic smart phone front end, with center frequency in the 1 to 5 GHz range, four orders of magnitude faster than a Spice simulation. The approach should be state-variable based and capable of the accurate simulation of arbitrary state variables (including multi-physics variables), physically correct true time delay, circuit memory effects, stochastic circuit and component variation, and greater than 140 dB dynamic range. Consider leveraging various macro-model techniques, such as behavioral modeling, advanced basis functions, tensor trains, and fractional calculus. Leverage published or commercially available macro-models. The simulator should provide a “dial an accuracy” capability to allow user tradeoff between accuracy and speed.

PHASE I: Demonstrate the feasibility of a software approach to linear and non-linear circuit simulation capable of simulating the detailed circuit response, sampled at any point in the circuit, to complex waveforms such as a 5G OFDM (Orthogonal Frequency Division Multiplexing) or CDMA (Code Division Multiple Access), pulsed ultra-wideband, multi-carrier, frequency hopping, and non-periodic pulsed frequencies. The simulator must accurately and efficiently handle circuit non-linearity, repeated transient behavior, and full duplex operation (with simultaneous very high and very low power signals). The feasibility of the approach will be supported by a block diagram of the software routines and analysis based on performance estimation from parameters reported in the literature for the various algorithms required. Results of research in the last two decades provide optimism that such a very high performance non-linear circuit simulator can be formulated. As an example, an advanced circuit solver approach (fREEDA), from North Carolina State University, is described in ref. 1, which has a dynamic range exceeding 160 dB in transient simulation. It is publically available for download (ref. 2). It has a physically correct true time delay capability (ref. 3), can accommodate arbitrary state variables and multi-physics variables (ref. 4), and can handle distributed networks (ref. 5).

Reference 11 is a link to a Sandia Laboratory generated circuit simulator (Xyce) which addresses many of the same issues as fREEDA. It is also publically available. Both have GPL public licenses. One approach to this topic would be to combine features from Xyce and fREEDA, since both can be leveraged for commercial application under their public licenses. Establish and present a transition plan for the software package, with details of specific transition partners and consideration of software documentation, maintenance and customer service.

PHASE II: Develop a trusted software package capable of the simulation described in phase I. Determine the fundamental limits of macro-models proposed and the measures of uncertainty introduced by each. Formulate a plan to demonstrate the capabilities of the simulation. Develop a validation plan for the simulator based on specific experiments and other limited capability simulators or simulations with extensive run time (which would not be practical for most applications). Demonstrate the simulation and validate against the criteria in the validation plan. Document the validation in a journal article for peer review which will effectively advertise and promote the simulation capabilities to the professional electronics community. Deliver a beta version of the software, including source code, to a designated government lab for testing. Provide on-site support of the government testing. Develop and deliver a comprehensive transition plan to make the software available to the government and commercial market place, with detailed outline of the roles of transition partners, an updated business model, and updated
market analysis. Develop and deliver a GUI (graphical user interface) with schematic capture integrated in the simulation. The software must be implemented in a common computer language such as C++ or Python. The simulator meeting these requirements will have significant capabilities not found in commercially available software and even (to our knowledge) in dedicated software internal to industrial programs. In particular the software will be capable of comprehensively simulating relatively long time steps and time delays (milliseconds) during (for example) an EW attack, of simulating with a scalable accuracy-vs-runtime tradeoff, of accurately modeling perfectly general waveforms in two circuits coupled at major distances electromagnetically, and easily encompassing the extensive device model libraries developed for other software products.

PHASE III DUAL USE APPLICATIONS: Develop a trusted software package capable of the simulation described in phase I. Determine the fundamental limits of macro-models proposed and the measures of uncertainty introduced by each. Formulate a plan to demonstrate the capabilities of the simulation. Develop a validation plan for the simulator based on specific experiments and other limited capability simulators or simulations with extensive run time (which would not be practical for most applications). Demonstrate the simulation and validate against the criteria in the validation plan. Document the validation in a journal article for peer review which will effectively advertise and promote the simulation capabilities to the professional electronics community. Deliver a beta version of the software, including source code, to a designated government lab for testing. Provide on-site support of the government testing. Develop and deliver a comprehensive transition plan to make the software available to the government and commercial market place, with detailed outline of the roles of transition partners, an updated business model, and updated market analysis. Develop and deliver a GUI (graphical user interface) with schematic capture integrated in the simulation. The software must be implemented in a common computer language such as C++ or Python. The simulator meeting these requirements will have significant capabilities not found in commercially available software and even (to our knowledge) in dedicated software internal to industrial programs. In particular the software will be capable of comprehensively simulating relatively long time steps and time delays (milliseconds) during (for example) an EW attack, of simulating with a scalable accuracy-vs-runtime tradeoff, of accurately modeling perfectly general waveforms in two circuits coupled at major distances electromagnetically, and easily encompassing the extensive device model libraries developed for other software products.

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KEYWORDS: circuit simulator, non-linear circuits, complex waveforms, 5G

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TITLE: 300W Low-Temperature SOFC Army Power Sources

RT&L FOCUS AREA(S): Microelectronics
TECHNOLOGY AREA(S): Materials

OBJECTIVE: Develop and integrate innovative materials and technologies to enable lowering the operating temperature of high power solid-oxide fuel cells to 300-600 °C.

DESCRIPTION: Advanced power sources are needed to provide electric power, which is critical to mission success, to soldiers during long-term missions especially in remote locations. Lightweight Solid Oxide Fuel Cells (SOFC) have been demonstrated that can provide power from gaseous and liquid fuels and offer the potential to provide this power from a wide variety of fuels including complex hydrocarbons, which are generally not amenable for use with other fuel cell technologies. Currently, solid oxide systems are too large, require long start times, and have low cycle lives. This is largely driven by the requirement of operating at very high temperatures (800-1000 °C) in conventional solid oxide fuel cells. Recent breakthroughs with triple conducting oxide perovskite and double perovskite materials such as BaCo0.4Fe0.4Zr0.1Y0.1O3-δ, NdBa0.5Sr0.5Co1.5Fe0.5O5+δ, and PrBa0.5Sr0.5Co1.5Fe0.5O5+δ have shown significant promise at low temperatures (300-600 °C) and power densities ranging from 650 to 1100 mW/cm2. Extremely high power densities of 2 W/cm2 at 650°C have been demonstrated from a bilayer-electrolyte LT-SOFC. These remarkable breakthroughs in low-temperature solid oxide fuel cell materials offer an opportunity to develop new high performance 300W LT-SOFC system that is capable of running hydrocarbon fuels, such as propane, and operating at 300-600 °C. This topic is focused on research to develop and integrate these new materials into solid oxide fuel systems to decrease weight and start up times while increasing cycle life. A lightweight (less than 3 kg) 350W+ (>150 W/kg system) low-temperature solid oxide fuel cell system is desired for a multitude of missions ranging from dismounted soldier power, UAV power, to silent watch applications. This technology could be used in a variety of roles including: direct power to Army systems or to charge lithium-ion rechargeable batteries which would significantly reduce the logistical burden (weight and volume) for dismounted soldiers by reducing the number of batteries required for extended mission time as well as for a myriad of civilian electronics applications.

PHASE I: In phase I a sub scale multicell stack using triple conductive oxide materials will be developed and evaluated using propane fuel. Stack performance data shall be evaluated and preliminary results from the stack should support the potential to develop a 3kg 300W+ system that operates below 600 °C, with a power density above 650 mW/cm2 and specific power 150 W/kg. Provide a detailed conceptual design of a 350W+ power system based upon the results generated in these efforts.

PHASE II: Based on the results from the successful phase I program, design, construct, assemble and evaluate a high performing 2.5kg 300W LT-SOFC system that operates below 600 °C, with performance degradation 4%/1000h, and lifetime 5000 hours under 350W+ power operation. Power density should be above 650 mW/cm2 and specific power 150 W/kg. Pursue the development of a system capable using liquid fuels, such as diesel or JP-8. Deliver 2 units to the Army for evaluation. Assess cost and manufacturability of demonstrated technology.
PHASE III DUAL USE APPLICATIONS: Based on the results from the successful phase I program, design, construct, assemble and evaluate a high performing 2.5kg 300W LT-SOFC system that operates below 600 °C, with performance degradation 4%/1000h, and lifetime 5000 hours under 350W+ power operation. Power density should be above 650 mW/cm2 and specific power 150 W/kg. Pursue the development of a system capable using liquid fuels, such as diesel or JP-8. Deliver 2 units to the Army for evaluation. Assess cost and manufacturability of demonstrated technology.

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KEYWORDS: Low temperature solid oxide fuel cell (LT-SOFC), Protonic ceramic fuel cell (PCFC), Solid oxide fuel cell (SOFC), Fuel cell, Soldier power.

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A20B-T004  TITLE: Photonic Accelerators for Artificial Neural Networks

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, Quantum Sciences
TECHNOLOGY AREA(S): Electronics

OBJECTIVE: To develop high-speed, scalable, power-efficient photonic accelerators for vector, matrix, and tensor operations with potential applications in artificial neural networks.

DESCRIPTION: In the post-Moore’s law era, electronic hardware accelerators [1,2] with parallel computing structures and optimized local memory for special-purpose computing, as oppose to CPUs for the general-purpose von Neumann computing, have enabled new applications that circumvent physical limitations of integrated circuits (IC). These accelerators include the well-known graphical processing units (GPUs) and tensor processing units (TPUs). Benefiting from these hardware accelerators, new applications based on artificial intelligence (AI)/machine learning (ML) that utilize artificial neural networks (ANN) have proliferated at virtually every corner in academia, industry and the society in general, despite the stagnation in raw IC processing power. In particular, deep-learning neural networks (DNN), consisting of many hidden layers, have shown the ability to generate solutions that are sometimes even superior to those based on human intelligence. For example, in 2016, the Google AlphaGo AI machines, after training for only two hours by playing with each other, beat the world’s best human player in the game of Go [16]. It is generally believed that the early success of AI in the last few years heralds a much wider array of AI solutions for both commercial and defense applications in the future. One of the examples of AI for defense applications is GPS-less navigation in the jammed battlefield, in which navigation is enabled by AI-based pattern recognition of scenes acquired in real time. The important role that electronic hardware accelerators played so far clearly indicate that future developments in ANNs depend on advances in both software and hardware. However, currently, electronic hardware accelerators have already been pushed to their limits in term of scalability. Against this backdrop, there have been renewed efforts in exploring the role of optics for computing [3-6]. Three major building blocks comprising the ANNs and DNNs are 1) Interconnects, 2) matrix-vector and matrix-matrix multiplication, and 3) nonlinearity. Since optics and photonics can implement the first two functions as well as, if not better than, electronics; and optical nonlinearity at the per neuron level rather than the logic level is actually quite practical, now is the right time to explore the role of optics and photonics in ANNs and DNNs. This topic focus on photonic accelerator for linear vector, matrix, and tensor operations.

PHASE I: To develop a photonic accelerator architecture, build a prototype and experimentally demonstrate the operational principle and feasibility of the photonic accelerator. The prototype should be able to perform at least 2 TOPS (tera operations per second), achieve a matrix loading speed > 100 MHz, and consumes no more than 0.5 W of electrical power. In addition, the layout of an integrated photonic accelerator with performance matching or exceeding the requirements for Phase II described below, and consistent with available fabrication platforms, should be developed.

PHASE II: To fabricate and test an integrated photonic accelerator that can perform at least 100 TOPS (tera operations per second), achieve a matrix loading speed > 500 MHz, and consumes no
more than 10 W of electrical power. Investigate the performance limits of the adopted photonic accelerator architecture in terms of computational dimensionality, computing power in units of TOPS, and power efficiency as functions of the input data rate and matrix loading speed. Production-scale costs of the photonic accelerator should be studied to show viability for reasonable cost reduction at manufacturing volumes. Motivation for phase III follow-on investment should be made evident.

PHASE III DUAL USE APPLICATIONS: To fabricate and test an integrated photonic accelerator that can perform at least 100 TOPS (tera operations per second), achieve a matrix loading speed > 500 MHz, and consumes no more than 10 W of electrical power. Investigate the performance limits of the adopted photonic accelerator architecture in terms of computational dimensionality, computing power in units of TOPS, and power efficiency as functions of the input data rate and matrix loading speed. Production-scale costs of the photonic accelerator should be studied to show viability for reasonable cost reduction at manufacturing volumes. Motivation for phase III follow-on investment should be made evident.

REFERENCES:

KEYWORDS: lasers, modulators, photodetector, optical computing, artificial intelligence, neural networks

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A20B-T005  TITLE: Cryo-CMOS Integrated Circuits

RT&L FOCUS AREA(S): Network Command, Control and Communications
TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: To develop integrated circuits based on nanoscale CMOS (complementary metal oxide semiconductor) technology for operation at deep cryogenic temperatures with low power consumption and enhanced noise performance.

DESCRIPTION: Digital electronic computer based on CMOS (complementary metal oxide semiconductor) technology is the driving force that fuels the modern data and information era. As the scaling of CMOS technology is quickly approaching its physical limit, energy scaling is becoming its bottleneck. Conversely, the advantages of operating CMOS transistors at cryogenic temperature (cryo-CMOS) have always intrigued CMOS circuit designers. A number of performance figures of merit of a CMOS process are improved when operating at low temperature without scaling down device sizes. Outstanding characteristics have been reported for advanced CMOS technologies operating at cryogenic temperature in terms of on-state current, leakage current, subthreshold swing, and transconductance. This is particularly attractive for high performance computing applications. The performance gain achieved from cooling down a CMOS integrated circuit should be judged against the cost and inconvenience of refrigeration in the context of its application. However, there are specific applications where CMOS circuits designed to operate at cryogenic temperature are advantageous. Cryogenic electronics plays an important role in sensing applications such as infrared focal plane arrays, space borne electronics, high-energy physics experiments, metrology, and astronomical detectors, and so on. Cryo-CMOS also finds its applications in the study of Quantum phenomena where low temperature is essential for minimizing thermal fluctuations. Qubits for quantum information processing typically operate at the temperature range of 10-100mK while the associated control electronics is implemented at room temperature. This approach becomes increasingly challenging and less cost-effective as the number of qubits grows. Control electronics operating at cryogenic temperatures placed right next to quantum circuits can drastically reduce interconnection complexity and noise level, and result in enhanced reliability and compactness, potentially paving the way for realizing practical quantum computers.

Even though Cryo-CMOS can be traced back to the 1960s, earlier research were performed on process nodes with large feature sizes resulting limited performance in terms of power consumption and noise. Development of nanoscale CMOS process with high intrinsic frequencies (ft, fmax ~100s GHz) offers new opportunities for realizing high performance cryo-CMOS circuits. This has led to recent demonstration of circuit blocks for quantum processing controllers (an LNA using 160-nm CMOS and a microwave oscillator using 40-nm) operating at 4 K. Device characterization at 4 k for a 28-nm bulk CMOS process has also been published recently.

Despite these progresses, many challenges remain for developing deep cyro-CMOS circuits. At the device level, unfavorable effects such as higher threshold voltage, hysteresis, kink effects, mismatch, and hot-carrier lifetime degradation become non-negligible at deep cryogenic temperatures, and must be considered and mitigated. Current refrigeration technologies have also
limited cooling power with 1mW at below 100mK and 1W at 4K, and thus prevent the use of large-scale cryo-CMOS circuits. Finally, lack of cryogenic device characterization, physical and compact circuit models and process design kits (PDKs) for circuit design simulators must also be overcome. This STTR topic will address device issues in order to enable development of cryo-CMOS technology.

PHASE I: Develop Low-temperature device characterization and modeling. Perform both DC and RF measurements on MOSFETs with different technology nodes and structural types (including bulk-MOSFET, finFET, FD-SOI) across the whole temperature region from room temperature to cryogenic temperature at 4 K or lower; extract the temperature-dependence of key parameters including Ion, Ioff, SS, Vt, RS, Cj, and S-matrix; investigate low-temperature effects including substrate freeze-out, kink effect, Vt mismatch, SS saturation, etc.; develop physics-based device models to match characterization; develop compact circuit models for use in circuit simulators. Phase I research will help identify one or more existing CMOS foundry processes for designing and fabricating cryo-CMOS prototype circuits in Phase II. The chosen processes must be thoroughly characterized and modeled during Phase I.

PHASE II: Design, fabricate and characterize prototype cryo-CMOS circuits against the CMOS foundry processes chosen in Phase I. The target operating temperature is at least 4 K, or lower. Prototype circuits to be demonstrated should include a low noise amplifier (LNA) and a microwave oscillator. The following metrics should be designed for operation at 4 K. The LNA should have >1GHz bandwidth, >60 dB gain, <0.1 dB noise figure across the bandwidth, and <80 mW total power dissipation. The oscillator should operate at 10 GHz, <1 KHz RMS frequency noise, <-140 dBC/Hz phase noise at 10 MHz offset, and <100 mW total power dissipation. Fabricate the circuits and characterize them at both room temperature and 4 K. Produce a process design kit (PDK) for deep cryogenic circuit against the CMOS foundry processes used in Phase II. Explore optimizing device layout within the processes for improving performance.

PHASE III DUAL USE APPLICATIONS: Design, fabricate and characterize prototype cryo-CMOS circuits against the CMOS foundry processes chosen in Phase I. The target operating temperature is at least 4 K, or lower. Prototype circuits to be demonstrated should include a low noise amplifier (LNA) and a microwave oscillator. The following metrics should be designed for operation at 4 K. The LNA should have >1GHz bandwidth, >60 dB gain, <0.1 dB noise figure across the bandwidth, and <80 mW total power dissipation. The oscillator should operate at 10 GHz, <1 KHz RMS frequency noise, <-140 dBC/Hz phase noise at 10 MHz offset, and <100 mW total power dissipation. Fabricate the circuits and characterize them at both room temperature and 4 K. Produce a process design kit (PDK) for deep cryogenic circuit against the CMOS foundry processes used in Phase II. Explore optimizing device layout within the processes for improving performance.

REFERENCES:

KEYWORDS: Quantum computing, CMOS, low power electronics, low noise, cryogenic

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TITLE: Virtual Off-Road Simulator for Teams of Bots and Autonomous/Conventional Wheeled/Tracked Vehicles

RT&L FOCUS AREA(S): Artificial Intelligence/Machine Learning, Quantum Sciences, Autonomy
TECHNOLOGY AREA(S): Ground Sea

OBJECTIVE: Establish an open source, publicly available software platform that can be used for the simulation-based development and testing of mixed teams of robots and Autonomous/Conventional wheeled/tracked vehicles operating off-road conditions.

DESCRIPTION: Understanding through physical testing the behavior of large groups of agents operating inter-dependent in geographic and terramechanical conditions that are of relevance to the US Army is an expensive proposition that suffers from long turnaround times. Against this backdrop, the Army sees computer simulation as an avenue for accelerating the pace at which innovation permeates the broad field of autonomous operation of mixed robot-vehicle teams in off-road scenarios. The interest is in establishing a simulation platform in which scenarios that involve teams of mixed agents are analyzed expeditiously with an eye towards improving mobility/communication/navigation solutions. Thus, the simulation platform sought should address several aspects deemed critical in the economy of the practical problem of interest, e.g. agent dynamics, sensing, inter-agent communication, real time constraints, scalability, and interfacing to control strategies. Moreover, in order to ensure a lasting effect of this investment, the solution developed should be open source and available in the public domain for rapid dissemination and adoption by any interested party.

The platform should simulate the dynamics of the agents and their interaction with the surrounding environment. This is particularly critical in evaluating or developing strategies used when terramechanics factors limit the capability of the vehicle (e.g., traversal of soft soils). Furthermore, the dynamics of the vehicle-ground interaction are exceedingly important and can require highly complex modeling of granular or other deformable terrain. Beyond model fidelity constraints, computational requirements must be considered such that the simulation meets real time or performance constraints determined by the task. Alongside dynamics, the simulation technology must be able to provide accurate virtual sensing as a mechanism to introduce realistic inputs to the control strategies being tested. The sensing requirements in off-road conditions for autonomous vehicles and robots are (a) sensing of the environment, e.g. camera (mono, stereo, thermal), LiDAR, radar, ultrasonic, GPS, and (b) sensing the agent’s own state, e.g. engine, driveline, suspension, brakes, IMU. This sensing simulation capability is critical as it provides the input to the control strategies used by the agent to navigate the virtual environment. While sensors provide a primary connection for the control algorithms to understand the world, these agents are also capable of inter-communication to collaborate and coordinate movements. This same capability must be provided in simulation to allow for testing connected behavior such as platooning and task coordination. Because the dynamics and sensing rely heavily on a coherent description (in both time and space) of their surroundings, management of the virtual world is a critical component of this simulation platform. The virtual world must provide an accurate representation for simulating the interaction of agents with the surrounding environment in off-road conditions. Given its correspondence to a highly rich feature set, the virtual world must...
include many layers including subsurface, surface, topography, vegetation, obstacles, other external agents (i.e. animals and humans), and environmental conditions. These layers must be coherent across domains such that the dynamics, camera (visible and thermal), LIDAR, radar, and ultrasonic simulations are all consistent.

PHASE I: In Phase I, the following shall be accomplished:

a) Carry out a comprehensive review of literature to produce a document detailing the state of the art vis-à-vis simulation environments for single and multiple-agent testing in both on-road and off-road conditions.

b) Establish a detailed plan to handle the four aspects (dynamics, sensing, communication, virtual world) related to the simulation of single- and multiple-agent testing in scenarios relevant to off-road operations.

c) Establish a detailed plan to address the modeling of the vehicle-terrain interaction at various levels of accuracy: from expeditious (empirical, data driven, etc.) to high fidelity (physics-based).

d) Establish a detailed plan for an open source implementation of the simulation platform that leverages parallel computing for scalability.

e) Articulate a vision for how the solution proposed, despite 3rd party software dependencies, will flourish as an open source simulation platform available for unfettered use, augmentation and distribution by other parties interested in this line of work.

f) Produce an early “demonstration of technology” prototype that showcases in a preliminary form the key components of the overall solution advanced by the project.

PHASE II: In Phase II, the following shall be accomplished: An open source simulation platform will be developed that:

a) Allows the simulation of tens of robots and autonomous/conventional wheeled/tracked vehicles operating in off-road conditions.

b) Allows simulation under “soft real time” as well as non-real time conditions.

c) Demonstrates use in deformable soil conditions

d) Possesses the interface to connect to any widely adopted control framework (e.g., ROS) and thus be able to serve as a testbed for new AI and emerging controls approaches aimed at enabling autonomy in off-road conditions typically associated with the Next Generation NATO Reference Mobility Model

e) Demonstrates the ability to simulate agent-to-agent and agent-to-infrastructure communication

f) Demonstrates the ability to emulate rich real-world scenarios that include, for instance, setups with deformable soils, various weather conditions, etc.

PHASE III DUAL USE APPLICATIONS: In Phase II, the following shall be accomplished: An open source simulation platform will be developed that:

a) Allows the simulation of tens of robots and autonomous/conventional wheeled/tracked vehicles operating in off-road conditions.

b) Allows simulation under “soft real time” as well as non-real time conditions.

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f) Demonstrates the ability to emulate rich real-world scenarios that include, for instance, setups with deformable soils, various weather conditions, etc.
REFERENCES:
3. Robotic Operating System (ROS), 2019

KEYWORDS: autonomous agents, computer simulation, sensing, V2X communication, dynamics simulation, open source software, artificial intelligence

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OBJECTIVE: To provide opportunity for scientific exploration of next-generation robotic and physical human augmentation performance systems and associated controls through development of actuation technologies, and the associated framework of predictive modeling.

DESCRIPTION: Currently human-scale robots and devices employed in human-scale physical augmentation devices and prosthetics employ mostly rotary-motion electric motors or hydraulics. We have made significant advances and demonstrations through design, fabrication methods, and controls in each of these technologies over the past several years, but they are still lacking in terms of performance, cost, and fundamental physics-based criteria for systems that are used in human-scale dynamic limb-based locomotion and whole-body manipulation. These forms of actuation have also been seen as limiting factors in development of machine morphologies which can replicate the degrees of freedom of human motion and human performance needed for human prosthetics and exoskeletons. There are examples of efficient and dynamic limb-based mechanisms which have been achieved through means of iterative design in which the systems mechanics and morphology are expertly matched with highly customized and optimized forms of actuation and unique electronic controllers. They represent a state of the art which has yet to be accepted as suitable for machines that are expected to perform as physical teammates to Soldiers in high-OPTEMPO missions.

This proposal seeks to continue further and spawn new research and commercialization for forms of robotic actuation and promote a mechanism design paradigm compatible with that of open, modular software development recently being adopted within the Department of Defense and academia. The goal is to provide examples of scalable forms of actuation (size and number) which may be seen as viable options for improving the performance and efficiency of next generation robotics mechanisms. New forms actuation which can deliver human scale forces and moments in lightweight and energy efficient configurations such as hydraulically amplified self-healing electrostatic (HASEL) soft actuators or other less common electrostatic-based actuators which have potential for making systems with less mass, less cost, and compatible with morphologies requiring distributed actuation are examples. Some of these forms of actuation may be seen as complementary to established actuators such as electric rotary actuators and hydraulics. For example, this may include actuated structures which have adaptive compliance characteristics. New electric rotary actuator and hydraulics based concepts may be considered as well. For example, limb-based human-scale dynamic locomotion and whole-body manipulation requires high-torque with high-frequency control. New scalable actuator designs addressing these requirements may be considered. For new rotary electric motor designs capable of offering improved suitable performance this could mean novel coil and magnet configurations combined with new motor controller sensing techniques which optimize force generated from magnetic field interaction.

PHASE I: In Phase I, the following shall be accomplished:
   a) Survey current design and approach for developing scalable actuator technology that may be employed for efficient dynamic human-scale whole-body manipulation and dynamic locomotion.
Review typical applications and regimes of interest, and identify relevant physical, electronic, software specifications and parameters to demonstrate the feasibility of an analytic and engineering infrastructure for their design, fabrication, and control.

b) Analyze and identify useful families of robotic morphology and/or structures in which the actuators may be employed.

c) Develop concept(s) through which the actuators or combinations of actuators may be employed and controlled feasibly to improve performance of human-scale robotic systems.

d) Implement the concept(s) numerically and conduct the appropriate proof-of-concept computations.

e) After the concept has been numerically demonstrated, use to fabricate a prototype or demonstration which validates numerical simulation.

PHASE II: In Phase II, the following shall be accomplished:

a) The actuator technology (actuator, actuator controller, actuator feedback) from Phase I will be tested, validated, and implemented. Aspects of efficient scalable performance and fabrication for efficient custom design will be demonstrated and characterized.

b) The actuator performance characterization models and control algorithm software and from will be tested, validated, and implemented as a documented software package that can be shared or distributed. The models should have compatibility with modern physics-based simulation software such that their performance may be predicted in a mechanical device.

c) Numerically demonstrate that models characterizing the actuator and performance are compatible with a modern physics-based robot simulation and that the information feedback from the actuators and/or actuation controller is suitable for whole-body manipulation control.

d) Numerically and in device tests, demonstrate that the actuator and controls software performs as predicted. This should be demonstrated at multiple scales (2x, 3x) or in the case of distributed actuators possibly different numbers (2x, 3x) of actuators.

e) Generalize the methodology in a-d to provide a range or families of actuators which may be readily simulated and fabricated for near-term and future human-scale robot use.

f) Develop and demonstrate fabrication method for the scalable range of actuators described above. Transition the developed methods and software, including documentation, to interested users in academia, industry and government (e.g. ARL) under appropriate licensing agreement.

PHASE III DUAL USE APPLICATIONS: In Phase II, the following shall be accomplished:

a) The actuator technology (actuator, actuator controller, actuator feedback) from Phase I will be tested, validated, and implemented. Aspects of efficient scalable performance and fabrication for efficient custom design will be demonstrated and characterized.

b) The actuator performance characterization models and control algorithm software and from will be tested, validated, and implemented as a documented software package that can be shared or distributed. The models should have compatibility with modern physics-based simulation software such that their performance may be predicted in a mechanical device.

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REFERENCES:

KEYWORDS: actuator, robot, exoskeleton, prosthetics, control, dynamics

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A20B-T008  TITLE: Physical Monitoring Techniques to Improve Warfighter Performance

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning
TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Develop multimodal wearable monitoring devices integrated with artificial intelligence-based decision aids for tracking biophysiological states, including cognitive, in the presence of various environmental and physiological stressors.

DESCRIPTION: The explosion of new wearable medical monitoring devices, miniaturized sensors, and artificial intelligence is providing new opportunities to optimize human performance and mitigate the effects of stressors that degrade performance and health within operational settings. Taking inspiration from the use of these technologies for improving the performance of professional athletes, the Department of Defense intends to optimize warfighter performance using similar techniques. The purpose of this topic is to explore technologies that will make tomorrow’s warfighter faster, smarter, and stronger than their adversaries.

The human performance focus area involves all aspects of cognition and decision-making, physiology and ergonomics, and the integrating technologies required to support a fully optimized, capable soldier; acting within a given operational setting. The goal of this is the optimization of individual and team performance in combat environments using a range of solutions, scalable across all leadership levels and command echelons. Human performance emphasizes the need to expand Warfighter capabilities while mitigating Warfighter limitations as they apply in combat.

To ensure mission superiority, the information about a Soldier’s mind-body state must be successfully acquired and understood within the context of the Warfighter’s cognitive capacity being stressed by fatigue, heat, altitude, interruptions, etc. This challenge is further magnified when a team or multiple teams are required to act together on the same mission. Methods and processes need to be explored that enhance peer-to-peer collaboration, shared situation awareness, and rapid decision making.

In the field, warfighters are exposed to a complex set of stressors affecting their physical and cognitive abilities; often altering their physiological well-being (e.g., sleep deprivation, biological rhythm changes, heavy equipment loads, demanding physical tasks, extreme weather/environmental conditions, and inadequate/improper nutrition). The impact of many of these stressors on performance is poorly understood and their combined effects on health and combat effectiveness are virtually unknown. Furthermore, what little is known about the mitigating effects of training and self-management on physical and physiologic viability has not been rigorously applied to the challenge of enhancing Warfighter performance nor has it been demonstrated to be viable in operational or synthetic training environments.

There is a need for a novel wearable monitoring solution to promote sustained performance and Warfighter health while helping to offset: 1) training related injuries during physical training across operational environments; 2) fatigue and other performance decrements in extreme environments combined with other stressors; 3) combat performance decrements related to sleep.
quality, sleep deprivation and sustained operations; 4) impacts of individual stress reactions during performance of operational tasks on overall warfighter health.

Gap 1: Insufficient understanding of individual physiological performance markers.
Gap 2: Insufficient understanding of the interaction between physical environment (stress, noise, fatigue hydration) and cognitive demands (workload, multitasking, and interruptions) on combat readiness and performance.
Gap 3: Inadequate automation methods to support information gathering, analysis, and processing leading to more effective and timely decisions at every command echelon.

PHASE I: Identify the proper form factor of a multimodal biophysiological wearable solution for combat and training environments. This solution should be evaluated for the appropriate sensors required to enable accurate classification of biophysiological states (e.g. from cardiac, respiratory, ambulatory and/or neural) and physical activities (running and climbing, etc). Continued evaluation of materials used in the form factor for strength and durability should begin during Phase I and can continue into Phase II.

PHASE II: Develop artificial intelligence algorithms for classification of multi-sensor biophysiological data while a subject is performing complex motion under varying environmental conditions. Customized sensors for motion and altitude may be required here. Phase II should include a pilot study to validate classification accuracy while the device is being worn during strenuous physical activities. Data analysis and classification should begin with the goal of identifying the appropriate state-space for providing individualized biophysiological state assessment.

PHASE III DUAL USE APPLICATIONS: Develop artificial intelligence algorithms for classification of multi-sensor biophysiological data while a subject is performing complex motion under varying environmental conditions. Customized sensors for motion and altitude may be required here. Phase II should include a pilot study to validate classification accuracy while the device is being worn during strenuous physical activities. Data analysis and classification should begin with the goal of identifying the appropriate state-space for providing individualized biophysiological state assessment.

REFERENCES:
KEYWORDS: Human Performance, Physical Training, Wearable Technology, Medical Wearables, Physiological Performance Markers

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TITLE: Three-Dimensional Microfabricated ion Traps for Quantum Sensing and Information Processing

RT&L FOCUS AREA(S): Quantum Sciences
TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Innovate, develop, demonstrate, and commercialize three-dimensional microfabricated ion traps needed for the robust and high-performance operation of ion-based quantum sensors, clocks, and other precision measurement systems.

DESCRIPTION: Recently several basic research advances Refs. (1-9) have been made in ion-trap quantum systems that have significantly improved the performance of these systems. These research advances include micro-fabricated surface ion traps that have been very successful in quantum technology applications. However, surface ion traps make many design compromises such as the trap depth, ion height from the surface, among others that may not be best suited for all potential quantum technology applications. In particular, anomalous ion heating and stray charges have been a significant hurdle to advancing ion trap experiments. Three-dimensional traps provide an alternate set of design parameters enabled by geometry that may overcome some of the compromises of surface ion traps. To date, typical microfabricated three-dimensional traps have been assembled by hand. The poor precision of hand assembly has significantly limited the performance of these three-dimensional traps. Modern microfabrication techniques such as additive manufacturing, three-dimensional printing, photo-chemical structuring of fused silica, among others, permit monolithic high-precision three-dimensional ion trap geometries to be pursued. In addition, three-dimensional geometry provides the space and path for innovative laser light delivery, microwave delivery, shielding, and wiring. The design trade-space provided by three-dimensional geometry, in combination with matched high-precision microfabrication techniques and new materials, provides the opportunity to develop high-performance integrated ion-trap quantum systems, while maintaining small size and form factor. There are several technical challenges that must be addressed that integrate the versatility of the design space of three-dimensional geometry with matched materials and monolithic micro-fabrication techniques. Machine-learning techniques may help optimize the design space combined with the constraints of fabrication and materials. Further research and development is needed that holistically views ion trap design and fabrication to address these challenges. For many potential applications, holistic designs must provide a high degree of optical access covering a wide range of wavelengths that can span the near ultra-violet to the near infra-red, microwave access, electrodes and electrode wiring for ion control, high operating voltages, and be compatible with other components needed for operating a complex ion-trap system. Room temperature operation is desired. Materials used must be compatible with ultrahigh vacuum processing and operation. Low residual magnetic fields are needed for magnetic sensor applications.

PHASE I: Innovations and explorations are needed with the design trade space offered by three-dimensional ion traps in combination with and matched to modern techniques for the high-precision microfabrication of these traps to develop a high-performance compact integrated ion-trap quantum system. Effort should focus on design and proof-of-concept demonstration of critical fabrication steps, materials, and system components comprising an integrated design of a three-dimensional ion trap, including optical and/or microwave access and electrode wiring.
Modeling and simple experiments should be performed to demonstrate feasibility of the proposed approach. An example application of trapped ions should be identified and used for the proof-of-concept demonstration of trap performance.

PHASE II: Finalize design and build prototypes of the three-dimensional microfabricated ion-trap quantum system. Provide a demonstration deployment that validates the technology at a laboratory that does suitable ion-trap quantum system experiments. The Phase-II program shall provide a plan to transition the technology to commercial development and deployment, wherein the three-dimensional traps are available for purchase by the user community.

PHASE III DUAL USE APPLICATIONS: Finalize design and build prototypes of the three-dimensional microfabricated ion-trap quantum system. Provide a demonstration deployment that validates the technology at a laboratory that does suitable ion-trap quantum system experiments. The Phase-II program shall provide a plan to transition the technology to commercial development and deployment, wherein the three-dimensional traps are available for purchase by the user community.

REFERENCES:

KEYWORDS: ion traps, three-dimensional ion traps, quantum sensors, quantum computing

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TITLE: Additive Manufacturing of Thermally Cured Thermoset Polymers

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

OBJECTIVE: Develop an additive manufacturing technique that allows for processing of thermally-cured thermoset polymers.

DESCRIPTION: Thermally cured thermosets, such as polyurethanes and polydimethylsiloxes (PDMS), are widely used in a myriad of industrial and military-relevant applications, such as machine parts, protective coatings, and medical devices, as they possess high thermal and mechanical stability. Additionally, as polymers, these materials possess the attractive features of being lightweight, ease of manufacturing relative to other high strength materials (e.g., metals/alloys), and inexpensive. Because of these attributes, thermally-cured thermosets currently dominate the traditional manufacturing space for thermoset materials. Highly desirable, however, is an additive manufacturing (AM) methodology amenable to processing these materials, as this would enable an “on demand”, energy-efficient means of their production. AM has also been demonstrated as a platform to rapidly fabricate customizable parts. This would be particularly impactful for DOD applications where manufacturing at the point of use may provide critical capabilities while decreasing and/or eliminating supply chain and logistical challenges.

To date, the difficulty in 3D printing thermally-cured thermosets largely stems from a need for extremely rapid heating/cooling cycles (sub microsecond) that span large temperature changes – a requirement that cannot be easily met using conventional bulk heating. Recently, researchers have demonstrated novel methods of internal heating using nanoscale heat sources, such as photothermal curing (ref 1), or pulsed microwave irradiation (ref 2) that could support the rapid cure cycles required with additive manufacturing. Additionally, the aforementioned photothermal curing method has demonstrated tunable mechanical and physical properties based on the intensity of light irradiation, thus offering potential access to 3D printed parts with tailored properties (ref 3).

There is an essential need to develop an additive manufacturing technique that enables the processing of purely thermally-cured thermoset polymers. The technique should also be generalizable include different types of thermally-cured thermosets. Additionally, the proposed method should not require an oven to fix the final print, and the final part should demonstrate mechanical and thermal stability akin to cast parts made from the same polymer formulation.

PHASE I: Develop a methodology that enables only thermally-activated curing of 1 of the following thermosets: epoxy-amines, PDMS, or polyurethanes, using only commercially available components. Please note that resins that are easily polymerized via photoinitiation, such as cationic epoxies and (meth)acrylates, will not be considered. The 3D printing technique should be capable of curing at the point of extrusion, and preferably not require and oven to fix the print. If an oven is used to post-cure, the printed part should be stable for 1hr prior to oven curing. The printer should have a minimal average speed of 10mm/s throughout a print and be able to continuously print for a minimum of 20 minutes. The technique should also demonstrate the ability to stop/restart after 10 minutes with no need to clean the printer. The final print part
should demonstrate a resolution (layer thickness and length) less than 1mm. 3DBenchy and other common 3D printing stress tests should be performed to ensure (i) the Young’s modulus, tensile strength, and glass transition temperature are similar to cast parts from the same polymer formulation, (ii) good adherence between layers, and (iii) solvent and light resistance similar to cast parts from the same polymer formulation. The performers should demonstrate the ability to systematically and controllably vary the thermal and mechanical properties to render parts that range from elastomeric to glassy.

PHASE II: Demonstrate the method developed in Phase I can be extend to use a different thermally-cured thermoset than the one the team selects in Phase I and should also extend Phase I capabilities to enable print speeds to a minimum of 50 mm/s continuously for 4 hours. Additionally, the printer should be able to change the resolution of the print (1mm to 0.1mm) and the print speed (10mm/s to 50mm/s), and also demonstrate the ability to print without user intervention. The final print parts for both classes of thermosets should demonstrate a resolution down to 0.1mm, enable printing of complex shapes, and demonstrate inclusion of specified hollow features. To validate the ability to cure and lock in the part, key structures should be printed. One such example include scaffolds and a mathematical geometric comparison of the printed geometry vs the expected geometry should be determined. Another example includes a tall structure, such as a cylinder, should be prepared to assess for slumping of the part as pressure from above layers could cause not fully cured towards the bottom of the part to flow and cause distortions and slumping of the part. Additionally, the final printed parts should demonstrate mechanical, thermal, and performance properties that exceed that of common AM resins. Solutions that also demonstrate the ability to monitor stress-development during cure, as well as the ability to co-print two different thermally-activated thermosets are highly desired.

PHASE III DUAL USE APPLICATIONS: Demonstrate the method developed in Phase I can be extend to use a different thermally-cured thermoset than the one the team selects in Phase I and should also extend Phase I capabilities to enable print speeds to a minimum of 50 mm/s continuously for 4 hours. Additionally, the printer should be able to change the resolution of the print (1mm to 0.1mm) and the print speed (10mm/s to 50mm/s), and also demonstrate the ability to print without user intervention. The final print parts for both classes of thermosets should demonstrate a resolution down to 0.1mm, enable printing of complex shapes, and demonstrate inclusion of specified hollow features. To validate the ability to cure and lock in the part, key structures should be printed. One such example include scaffolds and a mathematical geometric comparison of the printed geometry vs the expected geometry should be determined. Another example includes a tall structure, such as a cylinder, should be prepared to assess for slumping of the part as pressure from above layers could cause not fully cured towards the bottom of the part to flow and cause distortions and slumping of the part. Additionally, the final printed parts should demonstrate mechanical, thermal, and performance properties that exceed that of common AM resins. Solutions that also demonstrate the ability to monitor stress-development during cure, as well as the ability to co-print two different thermally-activated thermosets are highly desired.

REFERENCES:

KEYWORDS: thermoset polymers; additive manufacturing; 3D printing; polymer curing; mechanical stability

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TITLE: Cost Effective Synthesis of Linear Ring Opening Metathesis Polymers

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

OBJECTIVE: Develop and demonstrate a cost-effective method to produce linear ring opening metathesis polymers of poly(dicyclopentadiene).

DESCRIPTION: Recent work on ring opening metathesis-based polymers (ROMP) like poly(dicyclopentadiene) (pDCPD) and poly(ethylidene norbornene) (pENB) have shown remarkable high velocity impact performance 1, which is relevant for soldier and vehicle protection applications. Tailoring of the non-covalent interactions in crosslinked ROMP polymers with polar monomers has resulted in remarkable control over polymer modulus and strength 2, while linear non-polar ROMP polymers (i.e., those that are not crosslinked like pENB) have shown remarkable toughness and high velocity impact performance 3. This impact performance, however, can be degraded by oxidative or thermally driven crosslinking due to aging 4. Linear pDCPD that is resistant to crosslinking during aging would be particularly attractive due to the low cost of DCPD monomer, low polymer density, reasonable modulus and yield strength, high glass transition temperature, and low susceptibility to water degradation. So, ideal ROMP chemistries would involve linear polymerization of pDCPD along with the ability to tailor the polymer polarity and include stabilizing additives.

Currently available commercial strategies for polymerizing pDCPD result in crosslinked networks of polymers upon reaction facilitated by Grubbs catalyst or tungsten-based catalysts. These crosslinked systems have the following drawbacks: (1) they cannot be used in solvent-based processing (e.g., for composite prepreg production) due to insolubility in solvents and (2) high levels of crosslinking reduce the fracture toughness and can result in poor high velocity impact behavior. Furthermore, using monomers other than dicyclopentadiene (e.g., those that only linearly polymerize such as ethylidene norbornene) result in large increases in cost, making the materials no longer competitive with conventional structural resins. In contrast, linear poly(dicyclopentadiene) is expected to have the following decided advantages: (1) excellent high velocity impact performance and toughness, (2) potential for solution-based processing into composite prepgs and (3) the potential for polymerization of polar-group containing monomers (e.g., 5-norbornene-2-methanol) or post-processing heteroatom functionalization through secondary mechanisms.

Thus, we seek the development of novel techniques or novel use of existing techniques that can be used to synthesize linear ROMP polymers, specifically pDCPD and other monomers like 5-norbornene-2-methanol that are stable and resistant to environmentally driven crosslinking. This method must be usable with solvent and without solvent (neat) to allow for the full breadth of polymer processing options. The method should also provide a long shelf life for the linear pDCPD (i.e., it should prevent ambient crosslinking of linear polymers).

PHASE I: The offeror(s) shall develop a technique to synthesize linear polymers of dicyclopentadiene (100%) and co-polymers of other ROMP-capable monomers (e.g., 50%
DCPD and 50% of another monomer) both in solvent and in the absence of solvent (i.e., neat). The offeror(s) shall demonstrate the use of the solvent-less version of the method to fabricate 6 inch by 6 inch by 0.25 inch thick plates of material. The offeror(s) shall perform rheological or mechanical measurements of the entanglement molecular weight of the synthesized polymers and target overall polymer molecular weights that are 100 times higher than the entanglement molecular weight. The offeror(s) shall also perform a preliminary short (days to weeks) study of the environmental aging of the synthesized polymers to identify the mechanisms involved in undesirable crosslinking (e.g., oxidative aging or aging due to exposure to sunlight).

PHASE II: The offeror(s) shall expand the method developed in Phase I to the use of ROMP monomers containing polar functional groups (e.g., hydroxyl, carboxylic acid, epoxy) and surface-active groups (e.g., trimethoxysilane, thiols, phosphonic acids), again achieving both solvent-based and solvent-less synthesis. Alternatively, the offeror(s) may develop a method of functionalizing linear pDCPD post-synthesis with the groups listed above using a scalable, cost effective method. The offeror(s) shall further demonstrate the processability of the material by solvent casting 12 inch by 12 inch sheets of linear pDCPD and other linear ROMP polymers to thicknesses of 20-500 microns. 3D printing is not desired and will not be considered. Due to the unsaturated nature of pDCPD and other polymers, the offeror(s) will determine the longer term (months-years) aging characteristics of their fabricated polymers and develop means of arresting or mitigating aging (e.g., by using stabilizing additives or including such stabilizers in the polymer itself).

PHASE III DUAL USE APPLICATIONS: The offeror(s) shall expand the method developed in Phase I to the use of ROMP monomers containing polar functional groups (e.g., hydroxyl, carboxylic acid, epoxy) and surface-active groups (e.g., trimethoxysilane, thiols, phosphonic acids), again achieving both solvent-based and solvent-less synthesis. Alternatively, the offeror(s) may develop a method of functionalizing linear pDCPD post-synthesis with the groups listed above using a scalable, cost effective method. The offeror(s) shall further demonstrate the processability of the material by solvent casting 12 inch by 12 inch sheets of linear pDCPD and other linear ROMP polymers to thicknesses of 20-500 microns. 3D printing is not desired and will not be considered. Due to the unsaturated nature of pDCPD and other polymers, the offeror(s) will determine the longer term (months-years) aging characteristics of their fabricated polymers and develop means of arresting or mitigating aging (e.g., by using stabilizing additives or including such stabilizers in the polymer itself).

REFERENCES:
KEYWORDS: Polymerization, composites, manufacturing processes, fabrication, durability, ballistics, protection

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TITLE: An Accurate Missile Plume Flowfield and Signature Analysis Tool

RT&L FOCUS AREA(S): Hypersonics
TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Develop a methodology and analysis package for the accurate prediction of missile afterburning plume signatures capturing the effect of afterburning shutdown at high altitude.

DESCRIPTION: Predicting the emission signature and radar cross-section of rocket exhaust plumes is of vital interest to the Missile Defense Agency and the U.S. Army to protect the U.S. homeland and our forces abroad. Threat detection and identification can be enhanced by understanding the basic physics of rocket exhaust plumes interacting with the ambient atmosphere, in particular the phenomena of plume afterburning and afterburning shutdown. Plume afterburning is the combustion of rich rocket exhaust with the surrounding air, leading to increased plume temperatures and enhanced thermal emission up to altitudes on the order of 30 km. Accurately modeling this phenomenon depends on knowing the engine exhaust composition and conditions, the interaction of the engine exhaust with the base area of the rocket, and the flow field surrounding the vehicle. In addition, the turbulent combustion model must be capable of accurately capturing ignition, extinction, and reignition behavior in the plume shear layer while remaining computationally tractable. With the advancement of current sensor technology, the effects of turbulent combustion are now detectable and must be modeled.

PHASE I: Predicting the emission signature and radar cross-section of rocket exhaust plumes is of vital interest to the Missile Defense Agency and the U.S. Army to protect the U.S. homeland and our forces abroad. Threat detection and identification can be enhanced by understanding the basic physics of rocket exhaust plumes interacting with the ambient atmosphere, in particular the phenomena of plume afterburning and afterburning shutdown. Plume afterburning is the combustion of rich rocket exhaust with the surrounding air, leading to increased plume temperatures and enhanced thermal emission up to altitudes on the order of 30 km. Accurately modeling this phenomenon depends on knowing the engine exhaust composition and conditions, the interaction of the engine exhaust with the base area of the rocket, and the flow field surrounding the vehicle. In addition, the turbulent combustion model must be capable of accurately capturing ignition, extinction, and reignition behavior in the plume shear layer while remaining computationally tractable.

PHASE II: Implement the plan identified in Phase I to develop an integrated procedure to generate rocket plume flowfields that accurately capture the afterburning plume and afterburning shutdown phenomena. The metric is to include targeted experiments to confirm critical aspects of the CFD and turbulent combustion models. These models are expected to run within a reasonable time period and on a reasonable amount of computing resources. The model algorithm must be more efficient or reduce the chemistry mechanism (compared to current models) without enlarging the grid space or computational nodes. Additionally, identify approaches to incorporate the effect of particles in the plume and extract useful IR/UV/VIS/Radar signature predictions.
PHASE III DUAL USE APPLICATIONS: Implement the plan identified in Phase I to develop an integrated procedure to generate rocket plume flowfields that accurately capture the afterburning plume and afterburning shutdown phenomena. The metric is to include targeted experiments to confirm critical aspects of the CFD and turbulent combustion models. These models are expected to run within a reasonable time period and on a reasonable amount of computing resources. The model algorithm must be more efficient or reduce the chemistry mechanism (compared to current models) without enlarging the grid space or computational nodes. Additionally, identify approaches to incorporate the effect of particles in the plume and extract useful IR/UV/VIS/Radar signature predictions.

REFERENCES:

KEYWORDS: plume afterburning, turbulent combustion, reduced mechanism, ignition, extinction, reacting flow CFD

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TITLE: Quasi-Orthogonal Doppler Waveform Applications

OBJECTIVE: Develop one or more applications to demonstrate performance improvements within reciprocal bistatic or other multiple-channel radar systems achieved through the use of Quasi-Orthogonal Doppler waveforms.

DESCRIPTION: To address complex battlefields of the future the U.S. Army requires enhancements in the performance and multi-functional capabilities of bistatic and multiple-channel radar systems. To achieve such improvements the use of Quasi-Orthogonal Doppler waveforms is proposed. Systems utilize multiple transmitters emitting identical frequencies which include transmitter-induced Doppler frequency offsets. For example, if a pair of waveforms was transmitted with the first having the same starting phase on every pulse and the second having $n\pi$ radians of starting phase added for $1 \leq n \leq N$ pulses, where $N$ is the number of pulses in a coherent processing interval (CPI), the waveform returns could be separated on receive by using a low-pass and a high-pass filter.

As transmitted signals are finite in time thus their Doppler spectra will be infinite; however the waveforms can be separated by Doppler filtering. Hence they are considered to be quasi-orthogonal. Doppler-Division Multiple Access (DDMA) waveforms used in some Multiple-Input Multiple-Output (MIMO) radars are an example of quasi-orthogonal waveforms.

A reciprocal bistatic radar is defined to be a radar in which the two antennas can both transmit and receive. Simultaneously transmitting a signal from the first antenna (or element of an array antenna) and receiving it on a second antenna (or array element) would have the same propagation characteristics as transmitting a waveform on the second antenna (or array element) and receiving it on the first (to within the tolerances of the transmitter and receiver hardware). The two-way antenna patterns and propagation paths are therefore identical.

By transmitting a pair of quasi-orthogonal waveforms it is plausible to achieve novel range sidelobe suppression, simultaneous orthogonal polarization benefits, and other performance enhancements. For example, techniques such as Golay codes would have virtually identical sidelobe magnitude but opposite signs, causing the range sidelobes to become zero, independent of the antenna pattern, platform motion, time delay, etc. Also, polarization measurements could be made without distortions caused by the effects of pulse-to-pulse radar and target position changes. Cooperation of ground based radars using Quasi-Orthogonal Waveforms can lead to radar performance greater than the combination of single, non-cooperative radars.

PHASE I: Develop concepts and provide analysis of one or more applications of quasi-orthogonal Doppler waveforms in reciprocal bistatic, multistatic and or multiple-channel radar applications. The analysis will include factors that would impact the radar performance such as, performance estimates, simulation results, hardware requirements, effects of platform motions during a CPI, limitations and other factors relative to a conventional monostatic, bistatic,
multistatic or MIMO radar. This effort proposes one or more experiments that could be conducted to demonstrate these effects/concepts in Phase II.

PHASE II: Design and conduct hardware experiments demonstrating the performance highlighting benefits and limitations regarding the use of Quasi-Orthogonal Doppler waveforms in relation to conventional radar.

PHASE III DUAL USE APPLICATIONS: Design and conduct hardware experiments demonstrating the performance highlighting benefits and limitations regarding the use of Quasi-Orthogonal Doppler waveforms in relation to conventional radar.

REFERENCES:

KEYWORDS: Doppler Division Multiple Access (DDMA), quasi-orthogonal, reciprocal bistatic radar

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A20B-T014  TITLE: High-Speed III-V-Based Infrared Detectors with Selectable Internal Gain

RT&L FOCUS AREA(S): Quantum Sciences
TECHNOLOGY AREA(S): Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design and implementation of high-speed III-V quantum photodetectors for the mid- or long-wavelength infrared on commercially available substrates which provide bias-controllable internal current gain with limited excess noise.

DESCRIPTION: III-V infrared materials have undergone a rapid technical maturation. Superlattice-based absorbers have enabled access to infrared wavelengths beyond those available via bulk III-V alloys while remaining strain balanced to large commercially-available substrates. The simultaneous development of unipolar barriers and the nBn architecture has largely controlled unwanted shunt currents. As a result, high uniformity, large format (greater than HD) focal planes have been demonstrated using a commercial foundry business model1. The wide design space available for band engineering with III-V material systems offers flexibility for the design of future sensor systems.

Alongside higher pixel density for improved size, weight and power, future sensors will incorporate additional capabilities to achieve improved target detection at range. Detectors which can internally amplify their received photocurrent enable technologies such as range-gating for removal of obscurants/clutter or 3D imagery for computer vision or navigation. At the same time, these sensors should still be able to be used in a traditional passive imaging mode for situational awareness.

A drawback to internal detector gain is that it typically introduces an additional source of noise due to the uncertainty in the stochastic amplification process. HgCdTe, the incumbent avalanche photodiode technology in the midwave infrared (MWIR), has exceptionally low excess noise due to fortuitous electronic band structure at the alloy compositions in question2. Competing III-V materials will need to be designed to prevent or limit excess noise. This could be achieved at the material level3 (e.g. through engineering of carrier ionization coefficients) or preferably at the device level (e.g. by engineering amplification to occur deterministically only at certain locations via device architecture). The level of gain delivered by the device should be controlled by the applied bias and should operate in a linear mode – Geiger mode detectors are inappropriate for this imaging application. A final consideration is that detectors should have response times
suitable for frame rates which would achieve range resolution on the order of tens of centimeters.

Existing III-V commercial infrastructure, including growth foundries and focal plane array processors, will enable rapid adoption. Suitable technologies can be transitioned for insertion into future U.S. Army and other DoD systems, delivering multi-tasking sensors capable of multiple missions to the Warfighter. These sensors will enable improved target identification compared to traditional passive sensors, obscurant penetration, clutter rejection, and ranging for autonomous navigation and would directly benefit the Future Vertical Lift and Next Generation Combat Vehicle modernization priorities. Additionally, devices could have commercial applications in safety and security monitoring, aircraft warning systems, and in autonomous vehicles.

PHASE I: Determine the feasibility of novel absorption and multiplication material combinations compatible with commercial growth on GaSb or GaAs substrates which would be capable of linear-mode internal gain (>10) with response times suitable for range-gated imaging of man-sized targets (<0.5 nanoseconds) with limited excess noise (equivalent McIntyre model |k| < 2).

PHASE II: Execute growth, characterization, and fabrication plans developed in Phase I. Design layer growth recipe for MWIR or LWIR sensitive avalanche photodiode technologies determined in Phase I. Provide growth strategy with any experimental parametric variations to growth foundry for fabrication. Characterize growth efficacy (photoluminescence, crystallinity, defect density). Process large area test devices suitable for cryogenic testing. Demonstrate effectiveness of sensor at unity gain via quantum efficiency and dark current characterization. Quantitative metric goals will depend on targeted cutoff wavelength; preference will be given to proposals designed for >9µm operation. Demonstrate a linear-mode internal gain greater than 10 with response times below 0.5 nanoseconds and limited excess noise lower than a McIntyre model |k| = 2. Characterize gain and dark current as a function of bias and demonstrate transition between passive imaging mode and gained mode. Develop mini-arrays for small-pixel characterization. Investigate feasibility of small-format focal plane array development including specific features required for a compatible read-out integrated circuit.

PHASE III DUAL USE APPLICATIONS: Execute growth, characterization, and fabrication plans developed in Phase I. Design layer growth recipe for MWIR or LWIR sensitive avalanche photodiode technologies determined in Phase I. Provide growth strategy with any experimental parametric variations to growth foundry for fabrication. Characterize growth efficacy (photoluminescence, crystallinity, defect density). Process large area test devices suitable for cryogenic testing. Demonstrate effectiveness of sensor at unity gain via quantum efficiency and dark current characterization. Quantitative metric goals will depend on targeted cutoff wavelength; preference will be given to proposals designed for >9µm operation. Demonstrate a linear-mode internal gain greater than 10 with response times below 0.5 nanoseconds and limited excess noise lower than a McIntyre model |k| = 2. Characterize gain and dark current as a function of bias and demonstrate transition between passive imaging mode and gained mode. Develop mini-arrays for small-pixel characterization. Investigate feasibility of small-format focal plane array development including specific features required for a compatible read-out integrated circuit.
REFERENCES:

KEYWORDS: Infrared detectors, long wavelength infrared (LWIR), material growth, III-V material, avalanche photodiodes, gain, LADAR

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TITLE: Distributed Tactical Communications with LPD/LPI and AJ Capabilities in Heavily Congested or Contested RF Environments

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

OBJECTIVE: Develop a Distributed Tactical Communication System with beamforming to support low probability of detection (LPD) and interception (LPI) with anti-jam (AJ) properties under congested and/or contested radio frequency (RF) conditions.

DESCRIPTION: Based on the Army Modernization Priorities there is an urgent need to support communications in a contested and congested electromagnetic environment. Distributed beamforming offers the potential to maximize signal-to-noise ratio at the intended recipient while minimizing the residual signal in the environment that can be observed by adversarial sensors. Some current approaches leverage an advantaged node (or base station) that can communicate to a single cluster of dismounts acting as a distributed antenna array. The Army seeks more general approaches that support distributed beamforming between multiple clusters of dismounted nodes (i.e. squad-to-squad, platoon-to-platoon) that can function without the aid of a base station. The proposed approach should keep scalability in mind and account for a wide range of use cases including reach back communications to a distant vehicle that could act as a base station when available. The effort shall focus on balancing scalability while maintaining LPD/LPI and AJ capabilities. The described objective of the topic is tied to Army’s Non-Traditional Waveforms (NTW) effort and will address the gaps that exists now in the NTW approach. This proposed topic directly supports, the Army’s Network Modernization Priority with application to several other Army Priorities (e.g. fire support for Long Range Precision Fires).

Based on the prior research [1, 2, 3, and 4], the objective of the new technology to be developed under this STTR topic shall include:

- Utilizing both receive and transmit beamforming techniques
- Support dismount clusters (Squads) with at least 11 participants spaced 5m to 100m apart
- Communicate with the base which is mounted on a vehicle at a distance of at least 2 kms (threshold) with preferable distance of 5 kms (objective).
- Support squad to squad communication where the squads may be separated by 500 m or more
- Scale to a variety of dismounted combat team formation which can support dismounted IBCT, ABCT, and SBCT
- Provide voice and data modes
- Latency not to exceed 100 msec (lower the better)
- Scalable to support a network of up to 50 nodes
- Defined frequency range which can be supported with the proposed technical approach

PHASE I: Conduct a feasibility study that identifies and addresses the problems that must be overcome in order to successfully demonstrate the above listed capabilities. Demonstrate the feasibility at the bench level resulting in a TRL 4. Deliver a final report that covers the outcome of this study, performance specifications, any models developed, and future plan details.
PHASE II: Fabricate proof-of-concept prototype hardware to test, demonstrate and validate the feasibility of a beamforming system with the performance specifications listed above. These should be provided to a Government facility to assess performance of the system. The final report, TRL 5 prototype systems (5 units), prototype specifications and operation guide, and test reports will be delivered.

PHASE III DUAL USE APPLICATIONS: Productize the above system that can be demonstrated at TRL 6 by partnering with DOD vendor(s). This technology also has potential commercial applications, such as law enforcement and first responder communications, to enable range extension between clusters of low-power devices. These devices may be operating from low prime power constraints or may face transmit power restrictions due to FCC compliance. Such use cases are expected to expand with the emergence of the Internet of Things.

REFERENCES:

KEYWORDS: Dismounted Tactical Communication, LPI / LPD Communication, congested or contested RF environments Communication, AJ Communication

TPOC-1: Selvaraj Seetharaman
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A Capability for Measuring Attenuation and Backscatter of Experimental Microwave Aerosols

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

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To develop a methodology and a facility to measure attenuation and backscatter of a microwave-obscuring aerosol. In addition the system must be able to effectively disseminate small quantities.

DESCRIPTION: Smoke and obscurants play a crucial role in protecting the Warfighter by decreasing the electromagnetic energy available for the functioning of sensors, seekers, trackers, optical enhancement devices and the human eye. Recent advances in materials science now enable the production of precisely engineered obscurants with nanometer level control over particle size and shape. Numerical modeling and many measured results on metal nanorods affirm that more than order of magnitude increases over current performance levels are possible if high aspect-ratio conductive particles can be effectively disseminated as an unagglomerated aerosol cloud. By gaining a better understanding of the absorption and scattering properties of materials that are currently only available in lab scale quantities, future research can be better directed into areas that show the greatest promise.

PHASE I: Develop a methodology to measure attenuation and backscatter for a microwave-obscuring aerosol. Describe the test fixture required to prepare an experimental material sample, disseminate it, produce an aerosol and measure its attenuation, backscatter and concentration. Provide descriptions of the instrumentation/hardware required to scan from 2 – 40 GHz, produce an aerosol and make the measurements. Entire system should fit within a 15-feet wide by 15-feet long by 10-feet high room.

PHASE II: Fabricate, test and demonstrate a measurement system that meets the specifications developed in Phase I and with expanded capability for 2 – 150 GHz. Demonstrate that system can measure attenuation and backscatter of known materials (to be supplied by Army) to within 10% of published quantities. Prepare a cost estimate for building the system in quantity.

PHASE III DUAL USE APPLICATIONS: Fabricate, test and demonstrate a measurement system that meets the specifications developed in Phase I and with expanded capability for 2 –
150 GHz. Demonstrate that system can measure attenuation and backscatter of known materials (to be supplied by Army) to within 10% of published quantities. Prepare a cost estimate for building the system in quantity.

REFERENCES:

KEYWORDS: Microwave, attenuation, backscatter, concentration, dissemination, obscurants

TPOC-1: Zachary Zander
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A20B-T017  TITLE: Stereo Line-Scan Camera System For Surface Distress Identification

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)
TECHNOLOGY AREA(S): Ground Sea

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a near real time pavement imaging system, using a line-scan camera stereo pair which measures deflection depth trailing, and leads a moving wheel load on concrete & asphalt surfaces.

DESCRIPTION: The military pavements community is lacking in detail the true effects of vehicle-pavement interaction necessary to adequately adapt and validate more complex finite element models in the development of next generation combat vehicles (NGCV’s) and assessment of aging and contingency infrastructure. In assessing the physical influence of a tire moving along a pavement surface, research has centered on the measurement of stresses beneath a static or moving wheel load, and determining an assumed deflection basin surrounding the tire-pavement contact location based on pavement model parameters [1]. To advance the knowledge of how distresses are imparted to the pavement surface from vehicle or aircraft tires at varying loads, speeds, and pressures, current imaging techniques involve either the use of light detection and ranging systems (LiDAR), or line-scan laser systems, both of which have significant cost, and are complex to operate and interpret data [2]. Of interest to the Army and the broader commercial and academic sector is the potential of introducing the technology of low-cost line-scan camera pairs to create similar data quality of the laser systems, but adopting the more approachable photogrammetry point cloud development commonly used in modern full frame image processing [3].

Line-scan cameras have a long history of use in the manufacturing and food handling industries being utilized to rapidly detect defects in metal objects, food products, or other fast moving, repetitive objects. Further, newer color based line-scan cameras work effectively at imaging long continuous objects that are otherwise cumbersome to capture with a single photograph or scan, this technology is an ideal candidate for adaptation to rail or pavement systems [4]. Line-scan cameras can produce very detailed, sub-millimeter point clouds in real time, and combining two cameras in a stereo pair can create a depth map to coincide with the real time scan [5]. It is anticipated that this approach can achieve faster and more accurate point cloud rendering of the pavement surface than traditional photogrammetry and at a comparable accuracy to that of laser based systems, all in a more deployable and price-competitive system.
PHASE I: This research will involve demonstration of a stereo color-line-scan camera system that can measure surface deflection near a wheel load. The investigators will confirm whether smooth asphalt and concrete pavements provide sufficient point correspondences at line-scan resolutions for photogrammetric reconstruction. Whether the introduction of red green blue (RGB) pixels in place of grey-scale pixels influences feature detection should be investigated. Further, the influence of changing lighting conditions must be quantified and addressed.

This research will require development of algorithms that should provide depth data sufficient for determining deflections at every line-scan frame within a highly accurate (sub-cm) local or global reference frame. Algorithms produced from this effort should be deployable to a Windows (.NET) platform and should be written in an open-source, widely-used programming language.

PHASE II: Research at this phase will involve development of a deployable system that must include a stereo-pair of line-scan cameras for both the trailing and leading side of a moving wheel load. The reconstructed data from each stereo-pair should be fused for accuracy determination as well as to measure deflection differences in leading and trailing loading conditions. It is desired that the vertical and horizontal resolution of the developed line-scan camera system be tunable to match a variety of loading systems without excess data to accommodate variable tire configurations present within the military inventory. It is intended that during the Phase II effort, a demonstration of the system capability will include mounting of the stereo-pair system on the U.S. Army Engineer Research and Development Center (ERDC) Heavy Vehicle Simulator (a unique testing apparatus to the military pavements community) to capture pavement distresses on a moving aircraft wheel load.

PHASE III DUAL USE APPLICATIONS: Research at this phase will involve development of a deployable system that must include a stereo-pair of line-scan cameras for both the trailing and leading side of a moving wheel load. The reconstructed data from each stereo-pair should be fused for accuracy determination as well as to measure deflection differences in leading and trailing loading conditions. It is desired that the vertical and horizontal resolution of the developed line-scan camera system be tunable to match a variety of loading systems without excess data to accommodate variable tire configurations present within the military inventory. It is intended that during the Phase II effort, a demonstration of the system capability will include mounting of the stereo-pair system on the U.S. Army Engineer Research and Development Center (ERDC) Heavy Vehicle Simulator (a unique testing apparatus to the military pavements community) to capture pavement distresses on a moving aircraft wheel load.

REFERENCES:

KEYWORDS: line-scan; light detection; ranging systems; LiDAR; photogrammetric

TPOC-1: Ernest Berney
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TITLE: Tool Informed By Geomaterial Microstructure To Predict Electromagnetic Properties

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)
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 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a computational tool which integrates geomaterials chemistry and microstructure in 3D in order to predict bulk electromagnetic responses to various remote sensing modalities.

DESCRIPTION: This work focuses on the need to predict the electromagnetic properties of geomaterials such that computational prototyping of sensors and analysis procedures can be performed on an array of different material compositions to predict material response to a variety of remote sensing modalities. The needs focus on informing multi-physics based tools with 3D geo-material microstructures that include a heterogeneous mixture of chemical compositions, phases, particle size distributions, and porosity in their microstructures. Based on 3D solid microstructures with representatives volumes on the scale of centimeters and heterogeneity modeled on the scale of millimeters to 10s of micrometers, prediction of bulk electromagnetic properties is needed.

The goal of this work is to develop a computational tool that utilizes 3D microstructures of geomaterials such as concrete, rock, and soil with identification of phase, chemistry, porosity, particle size, and texture distributions and predict the electromagnetic properties and response to a variety of sensing modalities. Targeted sensing modalities span a wide range of the electromagnetic spectrum from visible to microwave and radar. As such, prediction of material properties including electrical, magnetic, and thermal is necessary. In addition, this will require an understanding of the propagation of various energy forms into and out of the material being interrogated.

PHASE I: Demonstrate the feasibility of integrating at least three different geomaterial types (e.g., concrete, rock, soil, or multiple or one or more types) that exhibit variations in chemistry, phase composition, and microstructure into a 3D model that predicts electromagnetic properties. The model may be a meso-scale multi-physics based model that discretely represents each phase or some other means to obtain bulk electromagnetic properties in a multi-phase heterogeneous material. Demonstrate the use of this model to predict basic electromagnetic properties including electrical, thermal, and magnetic properties. Demonstrate the use of these properties, along with
the 3D modeled microstructure, to predict the response of each material to one specific remote sensing modality such as an infrared or microwave spectrum. Deliver a report documenting the initial research activities under Phase 1 including the material analysis, simulations using the developed tool, and their initial demonstration to predict material response to various remote sensing modalities. The most effective tool will directly utilize 3D solid models of material microstructures including assigned phase structures and compositions to accurately predict electromagnetic properties. Tools that effectively predict properties when compared with physical measurements will be determined and proposed for Phase 2.

PHASE II: Advance the computational tool beyond initial versions developed under Phase 1 and exercise against a variety of geomaterials to predict response to a variety of remote sensing modalities. With materials supplied by the Government (three concretes, two rock types, and three soils), characterize and initialize the developed multi-physics modeling tool with material microstructures, constituent properties, etc and determine each material’s electromagnetic properties. Compare predictions of properties determined using the developed computational tool with physical measurements of these properties. Predict material response to contact and non-contact remote sensing modalities including hyperspectral, radar, etc. Then predicted responses should be validated against physical sensing systems using bench-scale experiments.

Deliver a reporting document that includes a description of each material, the characterization performed to ascertain the material’s microstructure, chemistry, particle size, or other relevant features, how these are integrated into the electromagnetic property prediction tool, and example uses of the tool to predict response to various remote sensing modalities. All algorithms, materials, experimental design, etc should be documented along with the performance of developed tools against each problem set examined.

PHASE III DUAL USE APPLICATIONS: Advance the computational tool beyond initial versions developed under Phase 1 and exercise against a variety of geomaterials to predict response to a variety of remote sensing modalities. With materials supplied by the Government (three concretes, two rock types, and three soils), characterize and initialize the developed multi-physics modeling tool with material microstructures, constituent properties, etc and determine each material’s electromagnetic properties. Compare predictions of properties determined using the developed computational tool with physical measurements of these properties. Predict material response to contact and non-contact remote sensing modalities including hyperspectral, radar, etc. Then predicted responses should be validated against physical sensing systems using bench-scale experiments.

Deliver a reporting document that includes a description of each material, the characterization performed to ascertain the material’s microstructure, chemistry, particle size, or other relevant features, how these are integrated into the electromagnetic property prediction tool, and example uses of the tool to predict response to various remote sensing modalities. All algorithms, materials, experimental design, etc should be documented along with the performance of developed tools against each problem set examined.

REFERENCES:
2. MI Khan, Factors affecting the thermal properties of concrete and applicability of its prediction models, 37(6) 2002.;
3. HC Rhim, O Buyukozturk, Electromagnetic Properties of Concrete at Microwave Frequency Range, 95(3) 1998.;

KEYWORDS: geomaterial; electromagnetic; microstructures; computational; prototyping; multiphysics

TPOC-1: Robert Moser
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A20B-T019    TITLE: Liquid Waste Utilization/Treatment with Energy Production

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)
TECHNOLOGY AREA(S): Ground Sea

OBJECTIVE: Develop novel solutions to produce energy and low tier water from black water and other high water content wastes to support distributed military operations.

DESCRIPTION: The Army needs improved capability to enable self-sufficiency and reduce sustainment demands during distributed operations. Black water and high water content wastes (e.g., food wastes) are both sources of waste that have a high potential for energy production. Instead of disposing them as wastes (at a high disposal cost), the Army proposes to develop a novel treatment/utilization method that will utilize them to produce water suitable for low tier applications in conjunction with generating energy for heating, cooling, or as stored electrical energy. The treatment/utilization system shall be able to treat mixtures of black water and high water-content wastes with a minimum Total Suspended Solid (TSS), Biochemical Oxygen Demand (BOD5), and Chemical Oxygen Demand (COD) of 1450, 1170, and 2930 mg/L, respectively.

The Army does not currently have the capability to treat black water or high water content wastes (e.g., food wastes) during expeditionary operations. Conventional approaches to treating or disposing these wastes are logistically intensive and increase the operational energy burden. Existing approaches to recover energy from wastewater are either large, slow, and/or require complex processes to convert products to useful energy. The goal of this topic is to spur novel integration of mechanical, electrical, chemical and biological processes to develop new technologies that maximize the performance of liquid waste treatment/utilization and energy production. The technology development will require holistic approaches to create a compact, robust, rapid, and simple utilization system that generate energy and produce water for low tier applications.

PHASE I: Project needs to demonstrate feasibility of the proposed technologies in a laboratory setting. Novel liquid waste treatment/utilization methods need to be tested and evaluated at the bench-scale for energy and low tier water production from mixture wastes of black water and high water content solid wastes. System analysis is required to verify the technology that can meet the requirements and address potential integration issues while showing a pathway to scale to a full sized system.

PHASE II: Based on the performance and design parameters elucidated in Phase I, a tricon (8x6.5x8') sized demonstrator needs to be designed, fabricated, and demonstrated. The demonstrator is required to be able to treat a minimum of 1500 gallons of liquid waste per day that produces water suitable for low tier uses and energy in the form of heating, cooling, or stored electrical energy for distributed military operations. The delivered demonstrator should be suitable for laboratory and field demonstration but the design does not need to be ready for manufacturing, nor is military standard durability required. The demonstrator shall be able to treat the black water and other wastes defined above while meeting the size and energy metrics of a full sized system.
PHASE III DUAL USE APPLICATIONS: Based on the performance and design parameters elucidated in Phase I, a tricon (8x6.5x8’) sized demonstrator needs to be designed, fabricated, and demonstrated. The demonstrator is required to be able to treat a minimum of 1500 gallons of liquid waste per day that produces water suitable for low tier uses and energy in the form of heating, cooling, or stored electrical energy for distributed military operations. The delivered demonstrator should be suitable for laboratory and field demonstration but the design does not need to be ready for manufacturing, nor is military standard durability required. The demonstrator shall be able to treat the black water and other wastes defined above while meeting the size and energy metrics of a full sized system.

REFERENCES:
1. U.S. Army Public Health Command’s TB MEDD 577 SANITARY CONTROL AND SURVEILLANCE OF FIELD WATER SUPPLIES http://phc.amedd.army.mil Note: This fully explains all field military operations that concern this topic author for the above topic;
2. Standard Methods for the Examination of Water and Wastewater, a joint publication of the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF). http://www.standardmethods.org/ Note: This reference is the benchmark for all analyses and source of approved methods for regulatory compliance.

KEYWORDS: water, water treatment/utilization, black water, wastewater, food waste, energy reduction, energy production

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TITLE: Validating Communications between Trusted and Untrusted Vehicle Control Systems

RT&L FOCUS AREA(S): Network Command, Control and Communications, Cybersecurity
TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: The idea is to implement a solution to decentralize and distributed blockchain security solution on the vehicle network to enable a form of incorruptible data and resiliency.

DESCRIPTION: Cybersecurity of the Army’s ground systems is a critical priority to national defense in the 21st century. Recent events have shown that modern commercial vehicles are vulnerable to attack and subversion through buggy or sometimes malicious devices that are present on intra-vehicle communication networks. The issue is current solutions require a centralize security measure such as an Intrusion Detection/Prevention System IDS/IPS to detect and/or prevent malicious communications. Since vehicles can be compromised at a single point yet effects can propagate across the entire vehicle, GVSC is looking for a solution that eliminates that single point of failure through a form of decentralized and distributed security validation to verify communications with certainty despite there being valid node on the network acting maliciously. GVSC would like to see this technology applied on an intra-vehicle communication network such as Controller Area Network (CAN) that can perform validation of messages in a form of decentralized security distributed amongst vehicle controllers as well as provide a sense of resiliency.

PHASE I: In the first phase of this effort, the contractor shall demonstrate a decentralized and distributed security solution that performs validation of communications on vehicle network such as Controller Area Network (CAN). The implemented technology shall have a low resource consumption on the vehicle network. In addition, message validations should minimally affect the vehicle network latency. The demonstration shall be a proof of concept in the form of a simulation or mathematical description.

PHASE II: Implement the concept developed in Phase I on real vehicle network such as Controller Area Network (CAN) using physical vehicle controllers. The contractor shall demonstrate the operation of the technology in a live vehicle or systems integration lab (SIL) environment. The demonstration shall include an ECU and at least one safety controller. The contractor shall validate the effectiveness of the technology by showing that other controllers reject valid but malicious messages sent by another controller. The contractor shall perform penetration testing with an independent team to identify other attack vectors against the technology.

PHASE III DUAL USE APPLICATIONS: Implement the concept developed in Phase I on real vehicle network such as Controller Area Network (CAN) using physical vehicle controllers. The contractor shall demonstrate the operation of the technology in a live vehicle or systems integration lab (SIL) environment. The demonstration shall include an ECU and at least one safety controller. The contractor shall validate the effectiveness of the technology by showing that other controllers reject valid but malicious messages sent by another controller. The
contractor shall perform penetration testing with an independent team to identify other attack vectors against the technology.

REFERENCES:


TPOC-1: Nicholas Bourcier
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TITLE: Physiological Status Monitoring Nanorobotics

RT&L FOCUS AREA(S): Biotechnology, Network Command, Control and Communications
TECHNOLOGY AREA(S): Bio Medical

OBJECTIVE: To explore the feasibility and effectiveness of a Wireless Physiological Status Monitoring Nanorobotic (Nanobot) capability that can be ingested by a casualty to provide streaming vital signs data.

DESCRIPTION: In the Multi-Domain Operation of 2030, all indications are that future operations will be significantly different than the recent past. The need for U.S. forces to use more innovative ways to overcome peer and near-peer challenges to outmaneuver adversaries. This different kind of warfare has already arrived with the hybrid warfare in the Middle East and Eastern Europe, which is leading to the next fight to be with violent intensity. American power and security will be challenged by peer and near-peer actors. To be ready, U.S. forces must effectively innovate and adapt concepts for the Multi-Domain Operation to shape the fight.

The U.S. military can no longer expect technology superiority in a Multi-Domain Operation and with expectation that communication and cyber systems will be compromised. In this environment, the service’s medical commands need to commence research into Virtual Health capabilities for the forward operational medics and corpsmen. These forward medical providers will be isolated, over tasked with casualties, and with limited supplies; innovative medical capabilities to support distributed operations will be a need for Prolonged Field Care in treating casualties for 24-72 hours before medical evacuation can occur. The need to monitor multiple casualties wirelessly will be essential and machine learning predictive algorithms will be a requirement in a no-communication prolonged care environment.

The Medical Capabilities provided by this Nanobot system will enhance medical personnel to continuously monitor multiple casualties at the same time, plus the data being presented will be used in upcoming Machine Learning Predictive Algorithms. The algorithms will provide medical personnel the tool to predict a patient’s status and provide up to 20 minute warnings when things are not going well. Also with machine learning tools and artificial intelligence, the medic will be provided treatment options to keep the casualty alive until evacuation to a higher level of care. In a no communication prolonged care environment, evacuating casualties maybe under medical personnel’s care from 24-72 hours. The Nanobot system is another tool to enhance medical personnel’s ability to monitor and treat multiple casualties during limited resources availability at the point of injury location.

PHASE I: Researchers will quantitative stage to identify and investigate futuristic capabilities of using medical nanobot technology that can be ingested to provide vital signs data wirelessly from the soldier/marine to a medic’s/corpsman’s End User Device (EUD) and provide feasibility documentation. Also, researchers will send out Requests for Information through the BAA to get an understanding of where industry and academia is on nanobot technology. These single or multiple nanobots will act as a physiological status monitor that will be ingestible and function for 24-72 hours or longer providing a wireless status of the soldier’s health. The possible concept will be that the soldier will have the medical sensor nanobot ingested prior to the
mission, the medic then will be able to monitor the soldier’s condition during the patrol and if the soldier is injured. The medical data coming wirelessly from the physiological status monitor will be received by the medic’s EUD which can be viewed by the medic and be alerted by predictive algorithms by any abnormal readings or anomalies.

This Phase will demonstrate the feasibility of the proposed approach through successful demonstration of breadboard concept of a Personal Status Monitor (PSM) Nanobot sensor, and will inform success criteria and performance metrics for the Phase II system design.

RESEARCH INVOLVING ANIMAL OR HUMAN SUBJECTS: The SBIR/STTR Programs discourage offerors from proposing to conduct Human or Animal Subject Research during Phase I due to the significant lead time required to prepare the documentation and obtain approval, which will delay the Phase I award.

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

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

PHASE II: From the results of the Phase I feasibility and effectiveness, develop a preliminary design of the PSM Nanobot system to develop a conceptual prototype that can possibly be taken to the field for initial concept demonstration of the technology with medics to provide usability and feasibility feedback toward the future development of the PSM Nanobot system. If a field research study and data collection event is possible, the medics attending can provide their guidance, feasibility of use, and recommendations on the continued development of the device. Consider developing a ruggedization plan for Phase III and Advance development.

Develop a commercialization plan. If an IRB is required during Phase II, submit an IRB package to US Army MRDC HRPO/IRB.

PHASE III DUAL USE APPLICATIONS: From the results of the Phase I feasibility and effectiveness, develop a preliminary design of the PSM Nanobot system to develop a conceptual prototype that can possibly be taken to the field for initial concept demonstration of the technology with medics to provide usability and feasibility feedback toward the future development of the PSM Nanobot system. If a field research study and data collection event is possible, the medics attending can provide their guidance, feasibility of use, and recommendations on the continued development of the device. Consider developing a ruggedization plan for Phase III and Advance development.
Develop a commercialization plan. If an IRB is required during Phase II, submit an IRB package to US Army MRDC HRPO/IRB.

REFERENCES:
5. Mobile Devices and Health, by Ida Sim, M.D., New England Journal of Medicine, 05Sep19

KEYWORDS: Nanorobots, Swarms, Teaming, Personal Status Monitoring, medical sensors

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TPOC-2: James Beach
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TITLE: To Develop and Demonstrate a Technology That Would Enable Precise, Multiplexed, Stepwise Modulation of Gene Expression (including single cell polymorphism) and Protein Levels in Mammalian Cells

RT&L FOCUS AREA(S): Biotechnology
TECHNOLOGY AREA(S): Bio Medical

OBJECTIVE: Develop/demonstrate a technology that enable precise, multiplexed, stepwise modulation of gene expression (including single nucleotide polymorphism and protein levels with the assessment of specific regions of interest.

DESCRIPTION: There are many host biomarkers, quantifiable indicators of a biological state, with clinical utility today. Single-analyte biomarkers, such as the erythrocyte sedimentation rate and C-reactive protein, have been utilized for decades as general markers of inflammation (Pearson et al 2003; Holcomb et al 2017). Single nucleotide polymorphism (SNP) of genes have been effectively connected to phenotypes; for instance Cytochrome P450 SNPs has been linked to metabolism rate of drugs (Abubakar, Bentley 2018, Deardorff et al 2018). However, while each biomarker has its diagnostic niche, most single-analyte biomarkers are associated with limited sensitivity and specificity and demonstrate efficacy only in highly focused clinical syndromes. Subtle changes in gene expression can have important biological consequences in cells (Michaels et al 2019). Multi-analyte markers to diseased state perturbations may offer the potential for greater specificity and broader applicability to a wide array of clinical settings. There are several examples of multi-analyte biomarkers that have already demonstrated diagnostic utility, including tests that measure gene expression, protein panels, metabolite panels, cytokine panels, and others. Since gene expression is rapidly altered in many cell types in response to a variety of exposures utilizing this information has several advantages. Furthermore, the widespread availability of quantitative reverse transcriptase PCR (qRT-PCR) platforms in clinical laboratories allows gene expression-based diagnostics to be more easily and directly translatable to patient care. Multi-analyte assays will provide high-resolution snapshots of complex physiology and further multiplexing of these markers will be highly relevant in the field as it moves forward.

Several gene expression techniques exist for quantifying gene expression (Padovan-Merhar et al 2003). Initially, low-throughput technologies were used to assess biomarkers composed of a small number of clearly defined genes. Unfortunately, qPCR can be labor intensive and time consuming and requires a large quantity of cDNA. Other possibilities include hybridization-based expression assays such as Nanostring™, Bioplex-based branched DNA assays (Qi et al 2016). The multiple steps from sample collection, RNA extraction, reverse transcription, and data acquisition provide opportunities for introduction of errors. The ability to examine a specific set of genes on a wide range of samples, using only minimal sample and reagents with a relatively short turnaround time for results with reduced man-hours per sample, makes the methods suitable for use in candidate gene validation and for use as clinical tools.

The aim of this STTR is to develop a method that delivers an unbiased answer to the biological question being asked by the researcher. The following factors should be considered when choosing a method for targeted gene expression analysis:

1. development of an automated procedure;
2. investigation is on targeted region(s) of specific gene(s) of interest
3. amount and character of sample requirements. Consider clinical samples, whole blood or saliva or urine could be sample of choice.
4. Multiplexing capability.
5. sensitivity and specificity of the assay proposed
6. robustness and simplicity of the method.
7. simplicity of software for analysis and interpretation of the data;
8. Effortless use of specialized equipment and reagents;
9. Turn-around time to result
10. Assay cost.

PHASE I: Given the short duration of Phase I, this phase should not encompass any human use testing that would require formal IRB approval. Phase I should focus on system design for gene expression and proteins assays using any gene/region of interest and data compared to housekeeping genes. Genes of interest can be selected from cytokine and interleukin genes and for the SNP CYP2D6 and CYP2C19 can be used for a proof of principle. At the end of this phase, a working prototype of the assay(s) should be completed and some demonstration of feasibility, integration, and/or operation of the prototype. In addition, descriptions of data analysis and interpretations concept and concerns should be outlined. Phase I should also include the detailed development of Phase II testing plan.

PHASE II: During this phase, the integrated system should undergo testing using some targeted genes/regions/proteins/SNP of interest for evaluation of the operation and effectiveness of utilizing an integrated system and its capability to demonstrate the utility in a diseased condition such as sepsis, coagulopathy, differential metabolism rate (poor vs. ultra-rapid metabolizer). Accuracy, reliability, and usability should be assessed. This testing should be controlled and rigorous. Statistical power should be adequate to document initial efficacy and feasibility of the assay. This phase should also demonstrate evidence of commercial viability of the tool. Accompanying the application should be standard protocols and procedures for its use and integration into ongoing programs. These protocols should be presented in multimedia format.

PHASE III DUAL USE APPLICATIONS: During this phase, the integrated system should undergo testing using some targeted genes/regions/proteins/SNP of interest for evaluation of the operation and effectiveness of utilizing an integrated system and its capability to demonstrate the utility in a diseased condition such as sepsis, coagulopathy, differential metabolism rate (poor vs. ultra-rapid metabolizer). Accuracy, reliability, and usability should be assessed. This testing should be controlled and rigorous. Statistical power should be adequate to document initial efficacy and feasibility of the assay. This phase should also demonstrate evidence of commercial viability of the tool. Accompanying the application should be standard protocols and procedures for its use and integration into ongoing programs. These protocols should be presented in multimedia format.

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KEYWORDS: Gene Expression, QPCR, Technology, Military Health, Soldier Lethality, Biomedical

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TITLE: Develop and Demonstrate a Portable Device for Bacteriophage Enrichment, Screening and Isolation Technology for Field Application

RT&L FOCUS AREA(S): Biotechnology
TECHNOLOGY AREA(S): Bio Medical

OBJECTIVE: Develop and demonstrate a portable technology to enable rapid bacteriophage (phage) enrichment, screening and isolation from suspension samples in remote and austere environments on user-selected permissive and target bacterial strains.

DESCRIPTION: Multidrug-resistant organisms (MDRO) have spread worldwide and triggered a major public health crisis. U.S. military service members wounded in combat are susceptible to infection by MDRO at a much higher rate than civilian population due to penetrating combat wounds being accompanied by foreign body inoculum (metal fragments, rocks, dirt), large zones of bone and soft tissue disruption, nerve damage and localized ischemia (tourniquet /edema), as well as severe hemorrhage with resuscitation (often severe, >10U) of 1:1:1 – pRBCs, plasma, and platelets that will systemically disturb overall physiology [immune system dysfunction, some degree of traumatic brain injury (TBI)]. Furthermore, the current concept of war into urban dense terrain (UDT) and multi-domain operations (MDO) are expected to generate complex wounds that will require advanced prolong field care and stabilization when tactical evacuations to robust rear element medical care infrastructures are delayed. In these instances, the potential for life threatening infection by MDRO is even higher and the need for solution is urgent. ESKAPEE pathogens (Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, Enterobacter spp., and Escherichia coli) frequently colonize healthy military personnel (1) and are causative agents of persistent infections of traumatic and burn wounds that are prone to biofilm formation and multidrug resistance (2). Limited to no options in antibiotic therapy warrants the development of alternative potent antibacterials, e.g. phages.

Phages are natural viruses that specifically kill bacteria to include pathogenic bacteria resistant to antibiotic treatment. Phages exhibit extraordinary specificity to target bacterial strains and can eliminate them without affecting normal microflora. A major advantage of phage therapy is the ability to exploit the constant natural evolution of phages to overcome phage resistance, infect and kill the host bacteria. Phages have demonstrated high efficacy against ESKAPEE infections in laboratory, domestic and farm animals and promising data in expanded access treatment of humans and even in recent clinical trials, especially in combination with antibiotics (3,4). Phages are becoming a very important adjunct therapy against MDR bacterial infections in civilian and military patients.

When multidrug-resistant bacterial strains are identified in geographic areas of interest, it is more efficient to search for co-located phages against these strains in environmental samples from the same geographic region. Thus, natural therapeutic phages are more likely to be in the host nations of interest where highly drug resistant organisms that infect wounded soldiers deployed in military operations reside such as OEF/OIF. From Soldier Lethality and performance perspective to include staying-in-the-fight, recovery and rehabilitation, the problem of infection by MDRO and ensuing sepsis or chronic infection has the solution for the infection near the site.
of injury. Although it is impractical to isolate phages under fire, the medical surveillance activities of pre-MDO could include surveillance of phages in area of interest so as to stage phage cocktails as adjuvant therapy. However, the ability to isolate and assess phages in remote areas away from a specialized laboratory does not yet exist.

PHASE I: Specimens currently have to be transported over long distances to a specialized laboratory for labor intensive phage enrichment and isolation procedures that will result in the loss of phages because of non-specific adsorption to particulate matter in samples and because phages are unstable at low titers (5,6).

The purpose of this STTR is to enable relatively rapid sample purification and sterilization, phage enrichment (propagation on a permissive strain of interest), screening of phages on target strains of interest, phage isolation and concentration in the field using a portable device at or near the site of specimen collection. The end product of the system sought through this process is a cocktail of phages with activity against strain of interest and system designs enabling individual phages are encouraged but not required. This capability will drastically improve force health protection at large but will more directly enable the formulation of better therapeutic phage cocktails using diverse phages with broad killing spectra isolated from remote areas around the world. The device should be easy to handle with minimal operator training. The technology should enable isolation, concentration, stabilization, and sterilization of natural phages. Users should have the freedom to select permissive and target screening strains of interest. The technology could be based on micro-filtration systems, microfluidics, centrifugation, nanomaterials, gel or polymer matrix or any combination of relevant technologies. The device can be a closed or open modular portable system.

The following features will be critical to consider when proposing a technology:

1. System should remove particulate matter from suspension without eliminating viable phage particles and sterilize the sample
2. System should enable users to select and input permissive strains of choice for phage propagation and target strains of choice for activity assessment
3. System should perform the enrichment (propagation) and concentration of viable phage particles
4. System should enable screening of phage activity against multiple target strains of interest
5. The field-deployable system may not exceed 30 lbs and none of its dimensions should exceed 16 inches, with minimal battery operation for 12 hrs.

PHASE I should focus on the design of proof-of-concept prototype technology/device that enables removal of debris from phage source suspension, sterilization and phage enrichment (propagation) on permissive strains of choice to produce a sterile enriched viable phage mix. At the end of this phase, working prototype (s) should demonstrate particulate removal, permissive strain input access and propagation capability of the system as well as post propagation stability and sterility of the cocktail of phages. Performance (i.e. turnaround time to enriched phage cocktails) should be compared to classical manual in vitro approaches over 24, 48, and 72 hrs.

PHASE II: PHASE II: During this phase, the integrated system should be refined to expand on the proof-of-concept into a product that enables high-throughput screening of cocktail of phages against diverse MDRO strains of choice. Further optimization of technology should miniaturize and ruggedize the device, combine additional access and incorporate phage enrichment step with screening on target strains and stabilization. This testing should be controlled and rigorous.
Testing and evaluation of the prototype to demonstrate operational effectiveness in simulated environments (i.e. extreme heat, cold, wet environment) should be demonstrated. Here, selected contractor may coordinate with WRAIR to collaborate in optimizing and validating system. This phase should also demonstrate evidence of commercial viability of the product and articulate plans to meet field-deployable requirements. Accompanying application instructions, simplified procedures, and training materials should be drafted in a multimedia format for use and integration of the product into market.

PHASE III DUAL USE APPLICATIONS: PHASE II: During this phase, the integrated system should be refined to expand on the proof-of-concept into a product that enables high-throughput screening of cocktail of phages against diverse MDRO strains of choice. Further optimization of technology should miniaturize and ruggedize the device, combine additional access and incorporate phage enrichment step with screening on target strains and stabilization. This testing should be controlled and rigorous. Testing and evaluation of the prototype to demonstrate operational effectiveness in simulated environments (i.e. extreme heat, cold, wet environment) should be demonstrated. Here, selected contractor may coordinate with WRAIR to collaborate in optimizing and validating system. This phase should also demonstrate evidence of commercial viability of the product and articulate plans to meet field-deployable requirements. Accompanying application instructions, simplified procedures, and training materials should be drafted in a multimedia format for use and integration of the product into market.

REFERENCES:

KEYWORDS: bacterial infections, multidrug resistance, phages as alternative antibacterials, environmental samples, debris removal, sterilization, phage enrichment, phage screening and separation, phage isolation, portable phage enrichment/isolation device, therapeu

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A20B-T024    TITLE: Soldier-borne Radar Detector

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

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: To design, fabricate, and demonstrate a radar early warning receiver for the dismounted soldier’s uniform, armor or battle kit that identifies and locates a Ground Surveillance Radar (GSR) threat.

DESCRIPTION: In the modern operating theater the dismounted warfighter faces a network of sensors searching from fixed and mobile ground and air platforms. Ground Surveillance Radar (GSR) or Battlefield Surveillance Radar (BSR) are long range sensor threats that can identify and track ground movement over kilometer scale distances, posing a threat of the maneuverability, survivability and ultimately the lethality of dismounted units. The ability to detect a GSR at a distance greater than its maximum range will turn the squad into a distributed sensor to locate advisory assets and take appropriate action.

Commercial GSR systems advertise single dismount detection ranges up to 23km [1]. With smaller man portable systems able to detect 12km with traditional pulse Doppler [2] or 9km with low probability of intercept (LPI) frequency modulated continuous wave (FMCW) [3]. Systems are also available coupled with day/night electro-optical sensors [4]. Threat systems are line of sight and maximum ranges assume systems are placed at sufficient elevation.

To contour the availability of these long-range systems the Government requires a radar early warning receiver for the individual dismounted soldier. Due to the ever-growing number of threats and potential technological capabilities for the dismounted warfighter, the Government must manage the total soldier burden of adding additional equipment to the battle kit. The Government therefore requires that this radar early warning receiver be a low profile integrated part of the uniform, armor or kit rather than an additional item mounted on the warfighter. The design should consider options such as wearable antennas and flexible electronics while considering associated challenges with these technologies for X and Ku Band (8-18 GHz) operation.

The system shall intercept and identify a GSR threat at a distance greater than its maximum range for detecting a single dismounted person. The system should also be capable of finding the
angle of arrival of the GSR signal and estimate the location of the emitter. Output will integrate with the Android Tactical Assault Kit (ATAK), a government owned mapping application, for communicating with the soldier. All members of a squad of 9 soldiers will have the receiver and will be networked through Bluetooth.

PHASE I: Phase I must show the feasibility of the technical approach through a demonstration of the preliminary designs including breadboard or demonstration board of electronic components, signal processing, electronic integration with uniform, armor, or soldier kit, and detailed plans for placement as well as size, weight and power. The sensor should capture sufficient information to identify the GSR system from a library of waveforms. It must also be able to find angle of arrival and estimate of the location relative the user. The system must perform for signals in the X and Ku Bands (8-18 GHz). It is not necessary to demonstrate the integration of the technology into a complete system, however, the planned technical approach and feasibility for system integration for Phase II must be included. Phase I deliverables will include, (1) a final report detailing technical approach, design, implementation, tests, data analysis, conclusions, and proposed path for integration with the soldier’s kit. (2) All test data. (3) A working breadboard prototype with software. Phase I deliverables do not have to be implemented on ATAK but this will be a requirement of subsequent phases.

PHASE II: Phase II will produce a prototype of a soldier worn radar early warning receiver that identifies and locates a Ground Surveillance Radar (GSR) threat. The system shall discriminate the threat from other radio frequency (RF) sources. The system shall be a low profile integrated part of the soldier’s kit rather than an additional item mounted on the warfighter. The system shall intercept and identify a GSR threat at a distance greater than its maximum range of detection for a single dismounted person. The system shall find the angle of arrival of the GSR signal and estimate the location of the emitter. Assume that the system is worn by all members of a 9 soldier squad. Location estimations shall improve as successive samples are collected and from aggregation of data from the detectors worn by all members of the squad. Software shall be implemented on the ATAK mapping platform and display to the user an estimation of the GSR location and detection range. The system must be ruggedized to operate in all operationally relevant environments, -30 – 125ºF high and low humidity, rain, dust, fog, etc. However, it must still be a low profile integrated part of the uniform, armor or kit rather than an additional item mounted on the warfighter. The system must operate in a cluttered RF environment with many signals and sources of electromagnetic interference. The final deliverable must also include an assessment of viability of producing the developed technology including an estimated system price.

Phase II deliverables will include, (1) a critical design review in which the contractor will provide in depth details on the design or their prototype system. (2) 4 copies of the prototype soldier worn radar detector system implemented on a smart phone running ATAK. (3) Source code for the ATAK application. (4) A final report detailing technical approach, design, implementation, tests, data analysis, and conclusions. (5) All test data.

PHASE III DUAL USE APPLICATIONS: Phase II will produce a prototype of a soldier worn radar early warning receiver that identifies and locates a Ground Surveillance Radar (GSR) threat. The system shall discriminate the threat from other radio frequency (RF) sources. The
system shall be a low profile integrated part of the soldier’s kit rather than an additional item mounted on the warfighter. The system shall intercept and identify a GSR threat at a distance greater than its maximum range of detection for a single dismounted person. The system shall find the angle of arrival of the GSR signal and estimate the location of the emitter. Assume that the system is worn by all members of a 9 soldier squad. Location estimations shall improve as successive samples are collected and from aggregation of data from the detectors worn by all members of the squad. Software shall be implemented on the ATAK mapping platform and display to the user an estimation of the GSR location and detection range. The system must be ruggedized to operate in all operationally relevant environments, -30 – 125ºF high and low humidity, rain, dust, fog, etc. However, it must still be a low profile integrated part of the uniform, armor or kit rather than an additional item mounted on the warfighter. The system must operate in a cluttered RF environment with many signals and sources of electromagnetic interference. The final deliverable must also include an assessment of viability of producing the developed technology including an estimated system price.

Phase II deliverables will include, (1) a critical design review in which the contractor will provide in depth details on the design or their prototype system. (2) 4 copies of the prototype soldier worn radar detector system implemented on a smart phone running ATAK. (3) Source code for the ATAK application. (4) A final report detailing technical approach, design, implementation, tests, data analysis, and conclusions. (5) All test data.

REFERENCES:

KEYWORDS: Radar, Radar Detector, Radar Early Warning Receiver, Wearable Electronics

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TITLE: Chemical Sensors for Toxic Industrial Chemicals/Toxic Industrial Materials (TICs/TIMs) Filtration Performance Monitoring

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

OBJECTIVE: To develop a prototype handheld device that provides a real-time assessment of the efficacy of a TICs/TIMs filter being used to purify water from any indigenous source.

DESCRIPTION: Soldiers require upwards of 15L of water/day to properly sustain adequate hydration levels on an extended mission. This water is either carried by the individual Soldier on their person in the form of the MOLLE hydration pack, canteens, and water bottles, or can be obtained from indigenous water sources in an emergency using purification tablets. Recent investment in filtration technologies by the US Army has led to the development of toxic industrial chemicals/toxic industrial materials (TICs/TIMs) filters that are compatible with the MOLLE hydration pack. However, there is no way to assess the continued efficacy of the filtration system, including when the filtration media is saturated or breached. In addition, although the filters have been developed to function for up to 135 L of water in a laboratory setting, there is no way to ensure that the filters would function as designed in an operational setting over their intended lifespan. The additional sources of fouling found in indigenous waters cannot be accounted for in the development and prototype stages.

Currently, the only way to assess water quality is to obtain a sample, send it back to a centralized laboratory facility, and obtain test results in 4-6 weeks. This is an unacceptable timeframe for a Soldier needing emergency water, and puts them at risk for acute or chronic health effects if they choose to drink the water without any knowledge of the risks.

Therefore, we are soliciting new ideas for a handheld sensor device that could provide assurance of water quality, after filtering, such that the Soldier could determine whether the filter is still functioning, or needs to be replaced. The sensor system shall sense for representative classes of TICs/TIMs (heavy metal, organophosphate, volatile), and salt in any source water. The limits of detection of the sensor should be commensurate with the Army Public Health Command minimum exposure levels for each class of threat. Higher consideration will be given to technologies that meet or approach the following guidelines:

- Handheld device or compatible with the MOLLE hydration system;
- Lightweight, with a total system weight not to exceed < 1lb/person;
- Simple sampling interface producing minimal waste;
- Minimal supplies to test against each class of threat;
- Provide instantaneous and easily understandable output of threats from the indigenous water source;
- Satisfy a 6 foot drop to concrete and 300 lbs dynamic and static compression while dry;
- No power/low power requirements are preferred. If batteries or other electronic components are required, they shall be commercially available and included in the total system weight for the entire service life of the device;
- Capable of being used and operated with water temperatures from 4°C to 49°C, in environments with temperature from -33°C to 52°C;
- System cost of <$200 at full scale manufacturing.

The device should be lightweight, easy to use, with a simple interface that provides an easy to understand readout.

PHASE I: The STTR Phase I should result in an innovative proof of concept device that incorporates sensing capabilities of at least three TIC/TIM threats, as well as salt, at concentrations equal to or below minimum exposure limits, defined by Army Public Health Command and TBMED 577. Phase I is to determine the scientific and technical merit and feasibility of the proposed cooperative effort. Phase I deliverables would include a bench scale demonstration of the technology, cost/benefit analysis report, a plan to scale technology, and technical report. Specifically, the device should be able to sense for threats from toxic industrial chemicals and materials, and high salt concentrations (>1000 ppm).

PHASE II: This phase of the program should expand upon the capabilities of the proof of concept devices from Phase I, to include sensing of at least 10 TIC/TIM threats, as well as salt, at concentrations equal to or below minimum exposure limits defined by Army Public Health Command and TBMED 577. Development should result in at least 10 useable prototypes, which shall be tested against artificial water spiked with threats, as well as real-world water sources (e.g. fresh, brackish, and seawater) to prove they meet the above requirements. Phase II deliverables would also include a final report documenting the development of the device, test results compared to the objectives and the technical data package to build the device, and a plan for commercialization.

PHASE III DUAL USE APPLICATIONS: This phase of the program should expand upon the capabilities of the proof of concept devices from Phase I, to include sensing of at least 10 TIC/TIM threats, as well as salt, at concentrations equal to or below minimum exposure limits defined by Army Public Health Command and TBMED 577. Development should result in at least 10 useable prototypes, which shall be tested against artificial water spiked with threats, as well as real-world water sources (e.g. fresh, brackish, and seawater) to prove they meet the above requirements. Phase II deliverables would also include a final report documenting the development of the device, test results compared to the objectives and the technical data package to build the device, and a plan for commercialization.

REFERENCES:
KEYWORDS: Hydration, sensor, individual protection, water, purification, Soldier, TICs/TIMs

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A20B-T026

TITLE: Robust, High Stretch, Flame Resistant, Breathable Textile for Lightweight Moisture Management

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

OBJECTIVE: To develop a fabric with the durability of a woven fabric and the stretch and breathability of a knitted fabric

DESCRIPTION: Current duty uniforms are made of woven fabrics however, the Army has fielded and has in acquisition garments with woven and knitted materials. The knit can only be placed in strategic locations where stretch and comfort are required and durability is not a critical issue. The use of a durable stretch fabric would increase the comfort and breathability of any woven garment. An FR material that provides the strength and abrasion resistance is needed to survive the wear and tear in the field and provide FR protection. The woven fabrics currently fielded are not as comfortable against the skin as knit fabrics, are not as breathable, and do not stretch enough isotropically to make the conformal fitting garments necessary for heat management and reduced bulk and movement hinderance. Knitted fabrics have very low durability compared to woven materials. Current methods for functionalizing woven fabrics often have detrimental effects to the intrinsic properties of the fabric such as durability, and air or water vapor permeation. This novel fabric should have robustness, stretch and breathability to allow for the design of a more comfortable, close fitting uniform that would increase thermal and moisture management of the wearer.

This novel textile should have the following properties:
1. Comfort of knit fabrics as measured in terms of bi-axial stretch, water vapor transport, wicking
2. Durability of woven fabrics as measured in terms of abrasion resistance, tear strength, bursting strength
3. The final weight and thickness of the textile should be comparable to the existing textiles used in standard duty uniforms
4. The textile should be no melt/no drip (T), flame resistance is required

To develop a fabric with the durability of a woven fabric and the stretch and breathability of a knitted fabric while retaining Army requirements for flame resistance (FR) and vector protection. The improved fabric properties will enable the manufacture of comfortable fabrics, conformal garments, with good heat management, and garments for a variety of applications both military and civilian. The new textile will have the above attributes and maintain the variety of finishing processes currently in use, including Dye-ability, permanent press and permethrin treatments.

PHASE I: Develop a proof of concept to incorporate durability, stretch, breathability, wicking, and comfort into a textile. Air permeation, stretch and recovery, flame resistance, moisture wicking, abrasion testing, and burst strength will be tested on the material IAW the ASTMS listed below in table 1.0. The detailed conditions of testing must be approved by the TPOC. At the end of Phase I, swatch sized samples will be delivered to the TPOC. Table 1.0 Phase 1 test methods and requirements will be uploaded with topic
PHASE II: The full scale manufacturing process must be demonstrated in Phase II. Further improvements on the textile properties are also the objectives of this phase of research, as needed. Full capability to sew into a garment must be demonstrated, seaming issues must be overcome. Continued testing on the scaled textile, as detailed in Phase I, will be conducted to ensure no loss in performance during scaled up production. This phase will demonstrate textile uniformity across the width and length of the production.

PHASE III DUAL USE APPLICATIONS: The full scale manufacturing process must be demonstrated in Phase II. Further improvements on the textile properties are also the objectives of this phase of research, as needed. Full capability to sew into a garment must be demonstrated, seaming issues must be overcome. Continued testing on the scaled textile, as detailed in Phase I, will be conducted to ensure no loss in performance during scaled up production. This phase will demonstrate textile uniformity across the width and length of the production.

REFERENCES:

KEYWORDS: Textiles, heat management, moisture management, stretch fabrics, fibers, nonwovens, fabrics

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OBJECTIVE: Develop a capability to maintain the accuracy, integrity and reliability of tracking dismounted soldier trainees as they perform their exercises in the field.

DESCRIPTION: The Army’s current modernization of live training requires accurate dismounted soldier trainee position/tracking to enable the convergence of Live, Virtual, and Constructive (LVC) training environments. Currently, live soldier trainees, when represented virtually, are often seen to have position jitter, or can be seen floating or jumping to positions not physically possible in the real world. Currently, under conditions of GPS satellite signal attenuation or blockage due to terrain features is conducted by a concept called dead reckoning, which is similar to a flywheel effect, which are relative estimates of position and heading using inertial sensors: accelerometers to measure linear motion, and gyroscopes to measure angular rate change. These sensors estimate position, velocity, and heading measured from a last known trusted GPS receiver position measurement (latitude and longitude) when the satellite signal reception is attenuated, distorted, or blocked by land features such as trees or buildings. Accelerometers simultaneously detect walking steps and estimate stride length to derive an estimate for position and velocity. Gyroscopes measure angular rate changes and are used to estimate heading. The last known GPS receiver position measurement also receives timestamps from received satellite signals that are referenced and tracked by crystal oscillators for keeping time reference measurements to estimate velocity. All of these sensors have error modes that degrade Position, Velocity, and Timing (PVT) measurement estimates proportional to distance travelled and elapsed time. Current state-of-the-art dead reckoning error rate is approximately 2% of distance travelled on flat, even, terrain.

We are seeking innovative dead reckoning techniques based on time series-based algorithmic solutions that exploit artificial neural networks that have PVT estimate error equal to, or less than, 0.2% of distance travelled and is able to maintain estimate performance in challenging terrain to include stairs, tunnels, and steep mountain terrain. Solutions using low cost Micro-electro Mechanical Systems (MEMS) based Inertial Measurement Units (IMUs) are preferred to keep cost, weight, and power consumption low.

Soldier trainees often perform their exercises in the field which are often in environments where GPS satellite signals are substantially degraded or altogether unavailable, such as during maneuvers in indoor urban training center buildings.

PHASE I: Develop detailed analysis of predicted performance and perform modeling and simulation of technical approach. Phase I deliverables will include a design concept and analysis of expected performance capability with supporting rationale.

PHASE II: Develop, demonstrate, and validate a proposed dead reckoning system using a Linux Operating System (OS) that meets the topic objectives. Phase II deliverables will be dead reckoning system prototype that can demonstrate meeting topic objectives in an outdoor test.
environment. The use of an Android smartphone to demonstrate the technology capability is acceptable. The proposed solution must be mounted on the body’s upper torso.

PHASE III DUAL USE APPLICATIONS: Develop, demonstrate, and validate a proposed dead reckoning system using a Linux Operating System (OS) that meets the topic objectives. Phase II deliverables will be dead reckoning system prototype that can demonstrate meeting topic objectives in an outdoor test environment. The use of an Android smartphone to demonstrate the technology capability is acceptable. The proposed solution must be mounted on the body’s upper torso.

REFERENCES:

KEYWORDS: Machine Learning, Neural Networks, Time Series Forecasting, Kalman Filter, and Pedestrian Dead Reckoning

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TITLE: Reducing COVID-19 Mortality by Reducing Post-Hyperimmunity Period Immune Suppression

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)
TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: To reduce soldier and civilian mortality from COVID-19 and other viruses by reducing post-hyperimmunity period immune suppression.

DESCRIPTION: Serious illness or trauma often induces a hyperimmune response, which marshals the body defenses to fight off the illness or effects of the trauma and promote survival. However the hyperinflammatory period is often followed by a period of immune suppression. During this period of immune suppression the patient often succumbs to the effects of microorganisms that would normally be easily neutralized. There is evidence to suggest that the intensity of the hypoimmune phase can be suppressed with compounds that are already part of the human diet and have already been demonstrated to be safe. The intent of this STTR call for proposals is to demonstrate and validate that increasing the amount of specific compounds in the human diet can improve survivability after COVID-19 infection, or to demonstrate that those humans that already consumed increased amounts of specific dietary factors have an increased survival rate. The ultimate intent is to then use that data and knowledge to prescribe specific dietary interventions to improve survival in humans facing severe biological challenges, whether civilians facing challenges such as COVID-19 or soldiers on the battlefield facing a wide variety of severe challenges such as IED injuries and trauma.

PHASE I: The investigators will obtain anonymized samples from COVID-19 patients and measure the levels of the candidate compound(s) in serum or other samples. Samples will be normalized by age, sex and other known risk factors and then mortality and recovery data will be gathered and used to determine whether higher levels correlate with increased survival. Data from phase I should clearly indicate that a phase II investment is justified.

PHASE II: In phase II the investigators will gather more samples if necessary. If the data supports human intervention trials then the investigators will obtain the necessary IRB approvals for a human trial. By the end of phase II the investigators will have either determined that 1) human mortality from challenges such as COVID-19 is reduced by dietary interventions that reduce the post hyperinflammatory period immune suppression or 2) COVID-19 survival cannot be increased by targeted altering of the human diet prior to infection.

PHASE III DUAL USE APPLICATIONS: In phase II the investigators will gather more samples if necessary. If the data supports human intervention trials then the investigators will obtain the necessary IRB approvals for a human trial. By the end of phase II the investigators will have either determined that 1) human mortality from challenges such as COVID-19 is reduced by dietary interventions that reduce the post hyperinflammatory period immune suppression or 2) COVID-19 survival cannot be increased by targeted altering of the human diet prior to infection.

REFERENCES:

KEYWORDS: COVID-19, hyperimmunity, immune suppression

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