**ARMY STTR 18.B**

**PROPOSAL SUBMISSION INSTRUCTIONS**

The approved 18.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 United States 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, the PMO relies on the collective knowledge and experience of scientists and engineers across nine Army organizations to put forward R/R&D topics that are consistent with their mission, organization, 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:

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**PHASE I PROPOSAL GUIDELINES**

Phase I proposals should address the feasibility of a solution to the topic. The Army anticipates funding two 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 $150,000 over a period not to exceed six months. Army STTR uses only government employee reviewers in a two-tiered review process. 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://sbir.defensebusiness.org/>) 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 5.4.e of the DoD BAA).

The Army requires your entire proposal to be submitted electronically through the DoD-wide SBIR/STTR Proposal Submission Web site (<https://sbir.defensebusiness.org/>). STTR Proposals consist of four volumes: Proposal Cover Sheet, Technical Volume, Cost Volume and Company Commercialization Report. The Army STTR Program does not accept submission of Volume 5, Supporting Documents, for 18.B Phase I proposals. The Army has established a 20-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 20-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 20-page limit. Any pages submitted beyond the 20-page limit will not be read or evaluated. If you experience problems uploading a proposal, call the DoD SBIR/STTR Help Desk at 1-800-348-0787 (9:00 am to 6:00 pm ET).

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 on the Army SBIR/STTR web page at <https://www.armysbir.army.mil/sttr/PhaseII.aspx>. The submission period in FY19 will be 30 calendar days. 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 Department of Defense 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 5, Supporting Documents, for FY19 Phase II proposals. The Technical Volume has a **38-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 towardthe 38-page limit.  ONLY the electronically generated Cover Sheets, Cost Volume and CCR are **excluded** from the 38-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 Phase II proposals submitted containing a Technical Volume over 38 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 $1,000,000.  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 $500,000; the second 10-12 months of funding should also be approximately $500,000. The entire Phase II effort should not exceed $1,000,000. 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 $500,000 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 ASSISTANCE (DTA)**

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 ten 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 DTA are described in section 4.22 of the DoD BAA.

**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.

**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 **$150,000** 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.

 4. STTR Phase I Proposals have four volumes: Proposal Cover Sheet, Technical Volume, Cost Volume and Company Commercialization Report.

 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/>.

 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 18.B Topic Index**

|  |  |
| --- | --- |
| A18B-T001 | Provably Unclonable Functions on Re-configurable Devices |
| A18B-T002 | W-Band RF Instrumentation |
| A18B-T003 | Additive Manufacturing Feedstock Designed for Uniform Printing of Metallic Builds |
| A18B-T004 | Carbon Nanotube Based Monolithic Millimeter-wave Integrated Circuits |
| A18B-T005 | Diffusiophoresis for Water Purification |
| A18B-T006 | Deep Ultraviolet Light Sources for Water Purification and Surface Sterilization |
| A18B-T007 | Resource Sharing Platforms for Improved Operational Logistics |
| A18B-T008 | Effective Human Teaming Supported by Social Sensing |
| A18B-T009 | Wavelet-Based Adaptive Antenna Systems |
| A18B-T010 | Mitigation of Ransomware |
| A18B-T011 | Software Tools for Scalable Quantum Validation and Verification |
| A18B-T012 | Hybrid Nano-Bio-Electronic Odor Detector |
| A18B-T013 | Disablement of Vehicles and/or Remote Weapon Stations in an Urban Environment |
| A18B-T014 | Robust High-Performance Laser Sources for Scalable Quantum Technology |
| A18B-T015 | Microporous Flexible Electrodes for Lithium Metal Secondary Batteries |
| A18B-T016 | Cell-Free Screening System for Genetically-Derived Small Molecule Biosensors |
| A18B-T017 | Millimeter-wave modulators for sparse aperture imagers |
| A18B-T018 | Rapid Prototyped 3D Printed Filters |
| A18B-T019 | Novel Manufacturing Techniques for Polymer/Metal-Organic Framework Systems |
| A18B-T020 | Sample Preparation Free Consumables for Ultra-Sensitive Chemical and Biological Detection from Complex Environmental and Clinical Matrices Compatible for Paper Spray Ionization Mass Spectrometry |
| A18B-T021 | Large Scale Nano-Crystalline Coatings For Penetration Resistance |
| A18B-T022 | Developing Long-Term Malarial Chemoprophylactic Drug Releasing Implant |
| A18B-T023 | Development of Radar Absorbent Textile Cloth for Soldier Uniforms |
| A18B-T024 | Novel Method for Functionalizing Fibers and Textiles |
| A18B-T025 | Squad Multipurpose Equipment Transporter (SMET) Tele-Operation Feedback System |

**ARMY STTR 18.B Topic Descriptions**

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| A18B-T001 | TITLE: Provably Unclonable Functions on Re-configurable Devices |

TECHNOLOGY AREA(S): Electronics, Sensors

OBJECTIVE: Sensitive battlefield communications require absolute verification of intended recipients. An effective protocol to authenticate communications can be defined using provably unclonable functions (PUF). By design, these functions depend on manufacturing variations and can uniquely identify specific instantiations of a device [1]. In most designs, a PUF requires specially designed circuits implemented within an application-specific integrated circuit (ASIC). As such these devices must be explicitly included in the communications hardware design, which can increase cost and preclude retrofitting fielded systems. An alternative solution is sought that can exploit re-configurable devices such as field programmable gate arrays (FPGA). Such a development will enable a low-cost software solution enabling hardware-authenticated communications in currently fielded systems.

DESCRIPTION: A requirement for securing the cyber battlespace is an ability to authenticate the recipients for sensitive data communications. To avoid being spoofed by a malicious network element, a transmitter must validate the identity of each recipient, which can be accomplished using unique hardware-dependent keys provided by provably unclonable functions (PUF) [1]. These specialized circuits exploit non-reproducible manufacturing variations to provide a device-dependent query that is effectively impossible to predict or replicate. Proposed PUF devices often assume specialized circuitry implemented in an application-specific integrated circuit (ASIC). A requirement to include an ASIC in a design can significantly increase system cost and complexity, especially when considering upgrades to existing and fielded systems. In contrast, a PUF that can be implemented using general-purpose, re-configurable hardware is extremely appealing. An effective PUF must exhibit extreme sensitivity to manufacturing variations, yet it must be deterministic in order to provide a consistent query response. A promising approach is to use chaotic dynamics in unclocked and unstable logic circuits implemented in a field programmable gate array (FPGA) [2,3]. Other approaches may also meet these requirements. To capitalize on recent advances, a novel approach is sought to develop a practical PUF realization that can be realized on a general purpose FPGA. Such a device should exhibit sufficient entropy to support unique component verification, yet it must be sufficiently deterministic to enable identification under various operating conditions. The intent of this solicitation is to develop a critical component that enables next-generation authenticated communication technology for a variety of applications. As such, the solicitation is not limited to a particular system or performance specification.

PHASE I: Conduct a design study with detailed model development for a PUF implementation using commercially available FPGA devices. Simulation, testing, and theoretical analysis will identify a preferred concept design. Consideration will be given to complexity, reliability, ease of integration with conventional systems, and a theoretical foundation to verify PUF operation.

PHASE II: Finalize a PUF design and demonstrate an implementation suitable for use in brass-board authenticated communication systems. Performance metrics will establish effective entropy metrics, consistency, reliability, resource requirements, and costs. Potential military and commercial applications will be identified and targeted for Phase III exploitation and commercialization.

PHASE III DUAL USE APPLICATIONS: The development of a FPGA provably unclonable function for device identification and authentication enables next-generation secure network communications. These technologies offer potential benefits across a wide swath of communications and sensor networks for both military and civilian applications. Some specific examples of possible applications are anonymous computation, software IP binding, and online hardware/software authentication for re-configurable platforms.

REFERENCES:

1. R. Maes, Physically Unclonable Functions. Springer-Verlag Berlin An, 2016.

2. D. P. Rosin, D. Rontani, D. J. Gauthier. Ultrafast physical generation of random numbers using hybrid Boolean networks, Phys. Rev. E 87, 040902R (2013).

3. S. D. Cohen. Structured scale dependence in the Lyapunov exponent of a Boolean chaotic map, Phys. Rev. E 91, 042917 (2015).

KEYWORDS: true, random, number, generation, entropy

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| A18B-T002 | TITLE: W-Band RF Instrumentation |

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the Announcement.

OBJECTIVE: Develop, prototype and prove out a repeatable and cost effective means of readily measuring W-Band RF field strengths (two ranges) while in field conditions and to a traceable control/reference baseline.

DESCRIPTION: Making accurate & traceable (calibrated) measurements of W-Band RF fields is challenging and time-consuming, even in a controlled laboratory, as it requires expensive instrumentation and procedures, with meticulous controls for assuring calibration and experimental repeat-ability. Performing these same system performance measures in less controlled environments (particularly outdoors) compounds these challenges. The core need is for a means of RF telemetry instrumentation which is inexpensive to acquire and operate, particularly for conditions outside of a benign laboratory environment, which will facilitate an automated self-calibration system that can be designed into an RF transmitter system.

The data collected is commonly used to verify basic RF transmitter function (output power, RF field strength (power density), RF field directionality/antenna beam focus) which has needs to be applied both "in beam" (achieving the design intent at target performance levels) as well as "out of beam" (for establishing RF field safety boundaries). The intended application can include highly directional high gain antennas (50+dB) which can result in peak field strengths as high as 100W/cm2, while the RF safety measures are low as 0.1mW/cm2 to 100mW/cm2 (traces to IEEE C95.1 Safety Values for Zone 0 / Zone 1 / Zone 2). Similarly, the application of the collected data may need to be expressed as instantaneous power and/or time-averaged power (or both), with an eventual goal of a real time data stream.

Challenges can be illustrated in current RF measurement methods. A collecting horn is good for increasing low field strengths, but are overwhelmed at high field strengths. Similarly, they are sensitive to polarity, physical positioning (misalignment) as well as field gradients (particularly in near field). Time-averaging using IR thermography on Carbon Loaded Teflon (CLT) sheets is simple, effective and polarity insensitive for high field strengths, but aren't capable of the low (safety-centric) field strengths, plus their trace-ability path back to a calibrated control values is indirect, and the hardware itself is prone to questions on if adequate calibration is being maintained, even before contemplation of effects of ambient temperature, humidity/moisture, winds, solar loads, or literal "wear".

Note: the primary W-Band target frequency is 95 +/- 3 GHz, and in two general field strength (power) ranges: (1): 0.1mW/cm2 to 100mW/cm2 (traces to IEEE C95.1 Safety Values for Zone 0 / Zone 1 / Zone 2) and (2): ~1W/cm2 to ~100W/cm2 (represents in-beam (focused) lower/upper engineering limits). While these field strength ranges contain a gap (between 100mW/cm2 and 1W/cm2), the solution should have no telemetry gap, but would incorporate an overlap. Similarly, because of the steep field gradient from high gain antennas, the solution for the lower power field range should not be prone to damage if/when it is unintentionally exposed to the higher power field.

PHASE I: During Phase I effort, the plan is to explore the specific requirements in greater depth & understanding, conduct baseline analysis & trades, calibration concepts & outline plans, and provide a pilot ‘breadboard’ concept demonstrator(s) for a feasibility check using a Government-supplied W-Band transmitter. Deliverables shall be final report (highlighting the pros/cons of various approaches), the breadboard, and recommended Phase II path forward. Deliverables should include consideration of unit costs on the concepts explored, such as to address having multiple sensors to collect multiple locations simultaneously (application of developing measurements for Safety Zones).

PHASE II: Develop the approach developed during phase I, with emphasis on the instrumentation requirements and calibration methodology; perform discrete feasibility experiments & provide data reduction & conclusions; initiate fabrication of system demonstrator. Conduct a series of tests as detailed which will prove out the technology and the fidelity of the calibration methods being used. The phase II final delivery should include the following:
• Robust demonstrator system – turnkey solution (hardware/software);
• Full system design, with calibration processes and resources (Executable and source code as developed);
• Test Report, detailing the key factors for calibration & maintenance of same;
• Operator’s Manual for use of demonstrator;
• White Paper on future technology growth into a fully automated self-calibrating RF system.

PHASE III DUAL USE APPLICATIONS: Refined and matured technology solution for a subsystem which will allow for RF transmitter systems to have automated self-calibration control of RF power /field strengths and of antenna field patterns (directionality/alignment, uniformity, focus/aiming). Commercial & Military applications will be able to integrate these telemetry systems to employ automated feedback loops for enhancing control over net total output power, power density, antenna alignment & focus for W-Band weapons & mm-W radars, and be an enabler for dynamic real time directional syncing of two way narrow-beam communications.

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1. Hati, A., Nelson, C.W., Nava, J.F. Garcia, Howe, D.A., Walls, F.L., Ascarrunz, H., Lanfranchi, J., Riddle, B., "W-Band Dual Channel AM/PM Noise Measurement System â€” An Update," Proceedings of the 37th Annual Precise Time and Time Interval Systems and Applications Meeting, Vancouver, Canada, August 2005, pp. 503-508.

2. Fralick, Dion T. "W-band free space permittivity measurement setup for candidate radome materials." (1997).

3. Scheiblauer, Stefan. "W-band for CubeSat Applications." https://artes.esa.int/funding/cubesat-based-w-band-channel-measurements-artes-51-3b033 (2016).

KEYWORDS: W-Band, RF, Measurement, Instrumentation, Calibration, Carbon Loaded Teflon, FLIR, Thermal Imaging

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| A18B-T003 | TITLE: Additive Manufacturing Feedstock Designed for Uniform Printing of Metallic Builds |

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Develop a feedstock metallic alloy that, despite the complex thermal processing cycle of the additive manufacturing process, enables 3D printing of builds with consistent mechanical properties and reliable performance.

DESCRIPTION: Additive manufacturing (AM) is of considerable interest to the Army as a prototyping method and a means to enable fabrication at the point of need (e.g. the Rapid Equipping Force's Mobile Expeditionary Lab [1]). While AM processing methodologies are well established for polymers, there are considerable challenges in creating reliable metallic components via 3D printing. Similar to what is observed in welding, a heat affected zone (HAZ) develops in the underlying layers of a build. This creates many potential problems: residual stresses, interior porosity due to lack of fusion and undesirable precipitate or grain structures [2-3]. In addition, the orientation of the part during the printing process creates significant anisotropy, a subtlety which many operators may not take into account [4]. While some issues can be mitigated by post-processing, this is not always desirable or available in remote locations. The issue of reliability is a key obstacle to the fabrication of metallic components via AM [2]. Determining the correct processing parameters for a metallic build is difficult and time consuming. Often, especially in a theater of war/remote location, it is not practical to develop a printing procedure when there is a very urgent need for a specific component or tool.

The bulk of research into AM metallurgy has been devoted to adjusting engineering alloys such as Ti 6-4 to be more amenable to the AM process [2,3]. This is because AM offers several potential advantages to fields such as aerospace or biomedical that demand complex parts of very specific alloys. Not all potential applications of AM require such high performance alloys. A soldier in a remote location requires a simpler but more reliable process to meet and adapt to evolving mission requirements in the field. Performance of the additive manufacturing process needs to be straightforward, with minimal a-priori technical knowledge of materials and manufacturing. It must be possible to quantify, with a high level of confidence, the reliability of the resulting product in order to appropriately assess the risk associated with its utilization as a field expedient solution. Currently, soldiers are using AM to print polymer tools and components to meet temporary or very specific needs [1,5]. An alloy designed to enable the simple production of metallic objects would be an asset by avoiding the prolonged process development normally required. The key features of such an alloy should be resistance to the formation of coarse processing defects, avoidance of undesirable precipitate or grain structures, and material properties as isotropic as possible with respect to build direction. Development of such an alloy is the objective of this STTR. This alloy should provide a means of simple and rapid production of basic structural tools or hard to source parts (e.g. containers, or frames) that address temporary or mission specific needs of the Army.

PHASE I: The proposal team will perform an exploratory study to investigate various alloy systems as potential candidates for a consistent additive manufacturing (AM) feedstock. The team should identify potential AM feedstock compositions, with suitability judged on the potential avoidance of interior processing defects, mechanisms to minimize anisotropy/residual stresses, and ease of developing the processing procedures. If necessary, the use of metallic elements with a low melting temperature such as lead and cadmium can be explored, although it is expected proper care will be taken to mitigate potential health hazards. CALPHAD (or equivalent computational thermodynamics tools) phase diagrams of candidate alloy systems should be produced and used to guide the selection process. These calculations should be adjusted to account for the highly variable conditions inherent to AM processing. Potential alloys should be evaluated under conditions that mimic the AM process to directly observe the solidification behavior of the alloy, compositional segregation and precipitate structures that occur. These experimental samples can be fabricated by either AM or powder metallurgy. At the end of Phase I the goal is to demonstrate a clear correlation, in terms of phases identified and micro-structural features observed, between experimental results and computational predictions that justifies the future development of the alloy.

PHASE II: The team will focus on the experimental and computational efforts to understand the micro-structure and evolution of the selected composition(s) in response to the additive manufacturing (AM) process. For clarification of any of the terms used to describe the Phase II tasks, (e.g., X-direction), please reference the ISO/ASTM 52921 and ASTM F2924 standards. Test components should be fabricated and characterized for both micro-structural and mechanical properties, with adjustments to the composition and processing procedure being made as necessary. The objective is the processing and testing of a minimum of twelve tensile specimens from a single powder or feedstock lot that meet the following criteria. The tensile specimens should be consistent with a standard size ASTM E8/E8M configuration, with six being printed in the X-direction orientation and six oriented in the Z-direction. Visual, ultrasonic, and radiographic examination should reveal no exterior or interior flaws that will compromise structural strength in any of the twelve specimens. The ultimate tensile strengths (UTS) of the samples should have a coefficient of variation of 3.5% or less between parts printed in the same orientation and be within 90% of the UTS of commercial alloys of comparable composition. A hypothesis test comparing the tensile results of the different build orientations should indicate that the mean strengths are not significantly different with a confidence of 95%. After completion of this criteria, a second set of twelve tensile standards should be fabricated on a separate AM machine. The statistical differences in results between these specimens and those obtained from the previous machine should be quantified.

PHASE III DUAL USE APPLICATIONS: The proposal team will develop the manufacturing process for commercial production of the alloy. Further adjustments to eliminate machine to machine variability should be made. Any treatments or practices necessary during or after the printing process will be determined and documented for the end user. Certification procedures for the powder or feedstock will be established. If necessary, substitutions for elements with potential health hazards, such as lead or cadmium, used in earlier experiments will be made. Software tools necessary to enable an operator to produce a component utilizing the AM process will be developed. At the end of Phase III, the new additive manufacturing alloy should be available for commercial and military purchase and use. The alloy can consist of powder, wire, or whichever feedstock type is best suited for the specific type of AM process it was developed for. The key aspect of the alloy is that it should enable relatively simple printing of metallic components in a manner analogous to what can be done currently with polymers. Ideally, an operator without a degree in materials and/or metallurgical engineering should be able to design and print a build, and utilize it for its intended purpose, with minimal consideration of complex factors such as internal stresses and warping, anisotropic material properties, or severe processing defects. Examples of components that might be built from this alloy include simple tools (silverware, screwdrivers, etc.), furniture, or complex prototypes or designs that would be difficult to machine.

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2. Frazier, William, "Metal Additive Manufacturing: A Review", Journal of Materials Engineering and Performance, Vol 23(6), June 2014, pp. 1917-1928

3. Zhang, Meixia; Liu, Changmeng, Shi, Xuezhi; Chen, Xianping; Chen, Cheng; Zuo, Jianhua; Lu, Jiping; and Ma, Shuyuan, "Residual Stress, Defects and Grain Morphology of Ti-6Al-4V Alloy Produced by Ultrasonic Impact Treatment Assisted Selective Laser Melting", Applied Sciences, Vol 6(11), Nov. 2016, article 304

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KEYWORDS: additive manufacturing, metals, 3D printing, uniformity, feedstock, alloy development, manufacturing process, manufacturing knowledge

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| A18B-T004 | TITLE: Carbon Nanotube Based Monolithic Millimeter-wave Integrated Circuits |

TECHNOLOGY AREA(S): Electronics, Sensors

OBJECTIVE: To develop a high performance carbon nanotube (CNT) based millimeter-wave transistor technology and demonstrate monolithic millimeter-wave integrated circuits (MMICs) based on this technology with improved power efficiency, linearity, noise and dynamic range performance over existing GaAs, SiGe and RF-CMOS technologies.

DESCRIPTION: Semiconducting single-walled carbon nanotubes (CNTs) have very desirable characteristics which are ideal for field-effect transistor (FET) channels, such as one-dimensional (1D) ballistic transport, high carrier mobility, inherent linearity and small size. Single-CNT FETs with room-temperature ballistic transport approaching the quantum conductance limit of 2Go=4e2/h=155uS was demonstrated more than a decade ago. It was predicted, based on extrapolation from individual CNT characteristics that FETs consisting of parallel arrays of CNTs will lead to significant improvement in energy-delay product and therefore speed and power consumption for logic devices, and enhanced linearity and efficiency for RF applications. Such an enabling technology will have a major impact in reducing size, weight, power and cost (SWAP-C) of electronic components.

However, these potentials were not fully realized due to a number of technical challenges: 1) the lack of techniques to eliminate tube-tube cross junctions and achieve parallel aligned CNT arrays with optimal packing density of CNTs; 2) the presence of metallic CNTs leading to less than ideal semiconducting purity; 3) difficulty of creating highly conductive ohmic contact to the CNT arrays.

A number of recent developments in the past few years have made significant progress in toward overcoming these challenges in sorting, processing, alignment and contacts of CNT arrays, and led to CNT FETs that could outperform conventional Si and GaAs FETs. For the first time, aligned parallel CNT arrays with higher than 99.98% semiconducting purity were realized on Silicon and quartz substrate. FETs built using these CNT arrays have realized room-temperature quasi-ballistic transport with channel conductance approaching the quantum conductance limit and 7 times higher than previous state-of-the-art CNT array FETs. Furthermore, high frequency FETs using well aligned CNT arrays deposited on quartz substrates have achieved current-gain cutoff frequency (ft) and maximum oscillation frequency (fmax) greater than 70 GHz. These breakthroughs in device performance offer the opportunity to finally utilize one-dimensional (1D) transport properties of thousands of aligned, gate-controllable conduction pathways possessing linear current density characteristics for improving high-frequency circuit performance. These newly demonstrated CNT FETs should show excellent performance at the microwave frequencies. However, in order to fully realize the potential of CNT FETs for millimeter-wave frequencies and higher, continued research within academic community is needed in order to achieve even higher ft and fmax, likely much greater than 100GHz, by further improvements in array purity, alignment and contact resistance. New approaches are also needed to realize large well-aligned, high-purity CNT arrays at the wafer-scale level for creating monolithic integrated circuits beyond individual devices.

The goal of this topic is to leverage these developments toward creating a high performance CNT-based transistor technology and wafer-scale monolithic integrated circuits at millimeter-wave frequencies that can be commercialized to outperform incumbent semiconductor high frequency technologies (GaAs, SiGe, RF-CMOS) yet at much lower cost.

PHASE I: Establish a robust process capable of producing high performance RF transistors based on CNTs. The process must be scalable to wafer size to enable fabrication of monolithic integrated circuits. Develop new pathways and process flow innovations in CNT alignment & deposition, material contact and doping to create high quality CNT arrays beyond current state-of-the-art for device engineering. In particular, prototype CNT RF transistors with the following metrics must be demonstrated in Phase I. DC: ION/W >500 ìA/ìm, ION/IOFF > 1000; RF: fT and fmax > 50GHz, and a third-order intercept (IP3) at least 10dB higher than its 1dB compression power (P1dB).

PHASE II: Demonstrate functional millimeter-wave monolithic integrated circuits that exceed GaAs, SiGe, RF-CMOS in DC and RF metrics based on the process developed in Phase I. Develop a hysteresis-free CMOS compatible process flow which can be integrated into an existing commercial CMOS process. Demonstrate improved device performance with the following metrics. DC: ION/W >700 ìA/ìm, gm/W > 700mS/mm; RF: fT > 130GHz, fmax > 180GHz, and a third-order intercept (IP3) at least 15dB higher than its 1dB compression power (P1dB). Functional circuits to be demonstrated should include a low noise amplifier with noise figure less than 2 dB and a power amplifier with output power greater than 30 dBm, both operating at 30 GHz.

PHASE III DUAL USE APPLICATIONS: To qualify the process with a trusted foundry in order to de-risk technology for monolithic heterogeneous integration with CMOS. Undertake reliability testing and radiation qualification. Produce a process design kit (PDK). Commercialize the technology via a trusted foundry for technology availability to the defense and military markets. CNT-based MMICs will have a variety of applications in the military, defense, aerospace and ultimately the consumer electronic markets.

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KEYWORDS: Carbon nanotubes, field-effect transistors, millimeter-wave, microwave monolithic integrated circuits (MMICs)

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| A18B-T005 | TITLE: Diffusiophoresis for Water Purification |

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Explore the use of diffusiophoresis to remove suspended particles and bacteria from water.

DESCRIPTION: Military operations frequently take place where safe drinking water is not available. Water has been 30 to 40% of the daily logistical burden in Iraq and Afghanistan, risking soldier lives with every water supply convoy. Soldier dehydration of 3 to 4% can reduce solider performance up to 48%. The universal unit level average water requirement is 25 L (25kg) of water per solider per day, with the requirement raising to 60L (60 kg) per solider per day for a fully developed theater. Currently, the Army uses a number of water purification technologies to meet this logistical burden, but these technologies introduce additional supplies into the logistics train (e.g. filters, membranes, and/or flocculation agents) for proper function and either require high energy costs associated with pumping or low efficiency by relying on sedimentation.

 An alternative methodology, based on diffusiophoresis, may be capable of providing continuous removal of suspended particulates and solutes from an aqueous stream. Diffusiophoresis is the induction of motion of suspended particles as a result of the presence of a concentration gradient. Membraneless water filtration has been recently demonstrated through the use of dissolved carbon dioxide (CO2) into a colloidal suspension. The dissociation of CO2 forms ions with substantial differences in diffusivities, leading to diffusion potentials significantly larger than ordinary salt gradients.

 The currently demonstrated process was conducted in micro-channels, which produced 2 µL/h at an estimated energy consumption (for a single channel and assuming 50% clean water recovery) on the order of 0.1 mW·h/L. In comparison to other filtration processes, this represents a potential decrease in filtration energy required by three orders of magnitude. Even when considering power for a total system based on diffusiophoresis, this represents a potentially revolutionary savings in power requirements. Such a process could also be used in conjunction with traditional membrane filtration to mitigate fouling.

 This filtration methodology is potentially scalable to outputs capable of meeting the above operational goals by creating arrays of micro-channels that share CO2 sources. Optimization of channel dimensions and concentration gradients, performance in the presence of salts, and removal of proteins or bacteria are all potential areas for improvements.

PHASE I: Demonstrate and optimize continuous diffusiophoresis without the use of membranes or filters to maximize particle removal from aqueous streams to achieve <1.0 nephelometric turbidity units (NTU). In addition, demonstrate capability to provide bacterial filtration for common water contaminants and demonstrate a path to remove 95% of bacteria from real-world freshwater sources (e.g. lake/river). Address basic scaling requirements of diffusiophoresis filtration for production of 25L of clean water per day from real-world freshwater sources, including size, weight, and total system power (to include CO2 generation from the atmosphere).

PHASE II: Continue optimization efforts to reduce turbidity to <0.5 nephelometric turbidity units (NTU). Demonstrate performance that meets or exceeds current state of the art (99.9% or better) reduction of bacterial contaminants from real world freshwater sources (e.g. lake/river). Sample source selection(s) should be coordinated with the Army prior to demonstration. Examine feasibility of purification from salinated sources. Examine feasibility of diffusiophoresis to provide filtration of other toxins, to include insecticides and heavy metal contaminants. Provide methodologies for deriving device designs from operational requirements on filtered output, power input and device size/weight.

PHASE III DUAL USE APPLICATIONS: Development of practical devices for both civilian (e.g. FEMA) and DoD use that represent a substantial reduction in either size, power, or both at output levels comparable to current technologies.

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KEYWORDS: Water purification, diffusiophoresis, turbidity

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| A18B-T006 | TITLE: Deep Ultraviolet Light Sources for Water Purification and Surface Sterilization |

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: To demonstrate high efficiency deep ultraviolet (UV-C) light sources at 219 nm and 265 nm spectral peak wavelengths for use in instrument sterilization and water purification systems. Reliable and efficient LEDs are desired that exceed 15% wall-plug efficiency.

DESCRIPTION: An efficient light source emitting at ~265 nm has been identified to be the most efficient wavelength for disinfection application [1]. To date, mercury vapor lamps have been predominantly used for these applications, which, however, are inefficient and produce mercury emissions to air, soil and water. In 2005 alone, over 2,000 tons of mercury was emitted to the environment, more than 10% of which was from mercury containing products such as mercury lamps. The need of a high efficiency, mercury-free solid-state deep ultraviolet lamp is therefore clear and urgent. AlGaN semiconductors have direct energy bandgap in the range of 6.2 eV to 3.4 eV, which have emerged as the material of choice for light emitters in the deep ultraviolet spectral range. To date, however, the highest external quantum efficiency for light emitting diodes (LEDs) operating at ~265 nm is limited to ~2%, or less [2]. Moreover, the wall-plug efficiency is generally below 1% for LEDs operating at wavelengths ~ 265 nm. Many factors contribute to the poor efficiency, including the presence of defects and dislocations in the device active region, the inefficient current conduction in wide bandgap AlGaN, and the unique TM polarization of light emission in Al-rich AlGaN. Recently, significant progress has been made to address these challenges. For example, AlGaN nanostructures can exhibit significantly reduced dislocation densities and enhanced current conduction. Deep ultraviolet light sources have been demonstrated with the use of these nanostructures [3-5].

This call seeks innovative proposals to develop efficient and compact deep ultraviolet solid-state lamps operating at ~265 nm. The devices should operate at a wall-plug efficiency level >15%, i.e. ~5-10 times better than the current state-of-the-art. The devices should exhibit long-term stable operation and deliver output power exceeding 100 mW required for effective and rapid disinfection. Moreover, the device size and weight should be considerably smaller than the conventional mercury lamps and should not contain any significant toxic materials. The final deliverable should include a fully packaged device with detailed testing results, including efficiency, output power, and estimated lifetime. Significant improvements over state-of-the-art efficiencies are sought. Nanostructured materials and light emitting active regions will be given strong consideration over standard approaches. However, while nanostructures are highlighted within this topic as a desirable method to improve material quality and light extraction efficiency, other approaches will be considered if effective at improving the current state-of-the-art in LED performance.

PHASE I: To demonstrate light emitting diodes operating at ~265 nm with efficiency >5%, and to further determine the technical feasibility for achieving a wall-plug efficiency >15% (for 219 nm the efficiency can be much less, approximately an order of magnitude). With the efficiencies mentioned, power output goals (minimum) of 20 mW and 2 mW at 265 nm and 219 nm, respectively should be achieved at 500 mA drive current. The size of the LEDs should be 0.5x0.5 mm. Detailed analysis of the predicted performance needs to be developed. A particular interest for improvement of wall-plug efficiency will be light extraction efficiency improvements. Assessment of LED possibilities at shorter wavelengths around 219 nm should also be made to include wall-plug efficiency estimates by the end of phase II work. The goal of the shorter wavelength LEDs is aimed at enhanced water purification and sterilization capabilities.

PHASE II: To develop, test, and demonstrate a prototype LED lamp operating at ~265 nm with efficiency >15%, and > and to further perform preliminary lifetime analysis. Power output goals (minimum) that should be achieved, with the efficiency goals mentioned for 265 nm (and much less for 219 nm), are 120 mW and 20 mW at 265 nm and 219 nm, respectively for 500 mA drive current (again, 0.5x0.5 mm dimensions). The LED lamp should be fully packaged and ready for field testing. Reliability and assessment of further efficiency improvements possible should be made to develop further phase III plans. Alternative wavelengths such as 219 nm should be pursued secondarily at some level for use in more thorough water purification scenarios (to remove other toxins for certain types of ground water). Design consideration of LEDs for uses for instrument sterilization and water purification systems should be made. In particular, light extraction illumination patterns of water or instruments to be sterilized. The need for reflectors or dispersers for uniform omnidirectional illumination should be assessed from a packaging and system perspective. Other wavelengths in the solar-blind spectral region such as 275 nm would be a third spectral band of interest for sensor systems. Goals for the spectral band should meet or exceed the 265 nm band regime.

PHASE III DUAL USE APPLICATIONS: Continue UV LED development with long-term reliability testing and efficiency improvements. Manufacturable epitaxial crystal growth and fabrication processed should be refined and developed for useful military water purification and surface sterilization products for scalable levels of throughput (both portable and larger systems are of interest). Requirements from USAMMA PMO-MD for health support roles of care 1-3 will be brought to play for relevant systems to replace current sterilization or water purification systems that suffer from large size, weight and cost issues. Commercial uses in water purification should also follow suit. Studies on the exact requirements of UV wavelengths and power levels can be made in accordance with Army and other medical purification and sterilization requirements. Follow-on uses for the LEDs in biomolecule sensors should be possible.

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KEYWORDS: Light emitting diode, LED, deep ultraviolet, AlGaN, water purification, disinfection, semiconductor, solid-state lamp, nanowire, nanostructures, light extraction efficiency

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| A18B-T007 | TITLE: Resource Sharing Platforms for Improved Operational Logistics |

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: To develop Machine Learning based scheduling algorithm(s) for sharing resources, which may be geographically distributed, in complex military environments that makes dynamic assignment of resources, to tasks, while accounting for constraints imposed by networked resources.

DESCRIPTION: Sharing platforms in civilian logistics (e.g. Airbnb, Uber/Lyft) have provided novel ways to implement logistics. By improving utilization of untapped resources, these platforms have led to increased efficiency. Recently, the adoption of sharing and pooling platforms has also been considered in military settings (see Braw (2016)). The current fiscal environment calls for more efficient utilization of military resources. However, sharing resources in a military environment exhibits unique features and requirements that pose research and implementation challenges:

-Uncertainty: Due to the complexity of military operations, the duration of resource consumption (or utilization) is uncertain and difficult to predict. Civilian platforms such as Airbnb exclusively deal with fixed-duration consumption requests. Uncertainty of resource consumption usually leads to under-utilization of resources and delays in satisfying demand requests.

-Networked resources: Instead of a single resource, requests typically pertain to a heterogeneous bundle of resources in a network configuration. In contrast, a car ride or a room rental consumes a single resource. Requests in the form of bundles introduces inter-dependencies between resources as well as other requests.

-Risk Management: Sharing platforms for military applications must incorporate risk management considerations that are absent in civilian applications. For example, in mission critical settings a minimum standard for quality of service must be guaranteed. Unlike civilian platforms for resource sharing in which priorities for resource allocation decisions are based on monetary transactions, military sharing platforms must make use of non-monetary mechanisms.

The main objective of this project is to develop and analyze implementable, data-driven algorithms that address challenges in managing large-scale sharing platforms with the above characteristics. The focus is on algorithms that match supply and demand, as well as algorithms that assign priorities in a manner consistent with operational doctrine. This type of large-scale algorithms have been elusive so far due to lack of reliable data on past resource consumption patterns. Recent developments in information technologies (e.g., real-time location systems, pervasive communications) and widespread implementation of electronic management systems are generating large volumes of operational data, which the developed approaches should be capable of utilizing.

PHASE I: To conceive, implement and test a new class of reservation algorithms in order to match real time supply and demand in ways that increases the overall system efficiency, as well as provide an opportunity for adequate planning. Viable and accurate schedules resulting from reservation algorithms are essential for efficient operation of resource sharing platforms in accordance with OPTEMPO. To achieve this objective, algorithms and software capable of producing efficient reservation schedules for resource sharing platforms with a large number of resources and requests must be developed (see e.g. Busic and Meyn (2015), Gurvich and Ward (2014)). The proposed set of methods must also incorporate risk and quality-of-service attributes in determining resource allocation. The final deliverable of Phase I will be a simulation testbed illustrating the benefits and trade-offs associated to the proposed algorithms in a specific military setting (e.g. battlefield logistics, sharing UAVs for surveillance and reconnaissance).

PHASE II: In light of significant uncertainty, reservation algorithms based upon historical averages of duration (the current state-of-the-art) will surely lead to significant discrepancies between planned and actual processes.
In Phase II, the objective is to develop fast machine learning techniques to complement the algorithms developed in Phase I so as to fully exploit updated information on statistical variability of resource consumption which will be fedback to update scheduling decisions according to algorithms proposed in Phase I. Synthetic data from simulated operations as well as forecasts from planned operations could be used as input for the learning task.
An additional objective for Phase II is to develop a networking architecture capable of supporting:

 -Platform Dynamics: Spatial and temporal movement of resources in the system. In some platforms, the dynamics are primarily temporal (when resources get occupied and freed); in vehicle sharing, they are spatio-temporal.

 -Resource Constraints: These determine the possible states of the system and the set of allowed matches in each state. In vehicle sharing, the state space is the location and type (free/in-use) of each vehicle; feasible matches require demand to arrive at stations with free vehicles. For other platforms, the state space is whether each resource is free/occupied; allowed matches depend on compatibility between customers and resources.

 -Request Dynamics: These can be one-sided (typically when supply is fixed), or two-sided (where both demand and supply actively participate).

PHASE III DUAL USE APPLICATIONS: In Phase III, the software developed in Phases I and II will be made available for military and civilian use (e.g. sharing platform for complex logistic operations). We envision that the team that develops the software will market it for Government laboratory use, and negotiate commercial licensing with commercial and academic markets. As an alternative, any or all of these artifacts might be released into the open source community. Based on negotiations with the types of government and commercial organizations cited, it is possible that hybrid commercial and open source licensing could occur. In the case where these artifacts are released into the open source community, the STTR awardee would need to develop and provide a plan to state how it would sell additional consulting, software implementation and/or training services around their workflow model, technical implementation guidelines, and/or software controls.

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KEYWORDS: sharing platforms, army logistics, real-time matching

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| A18B-T008 | TITLE: Effective Human Teaming Supported by Social Sensing |

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Develop and deliver a standalone social sensing platform for behavioral analysis of small team interactions providing teamwork diagnostics and intelligent decision-support software capabilities to track, manage, and significantly impact team readiness and performance.

DESCRIPTION: Advances in information and network technology continue to transform the way human organizations communicate and operate. So much so that networked organizations lie at the core of the political, military, economic, and social fabric. Massive volumes of data that characterize online 'digital behaviors' including communication and collaboration, are increasingly collected and subjected to data mining by companies, governments, and researchers alike [1,2,3,4]. Recent advances in the collection of 'analog behaviors' with the pervasiveness of sensor technology - from smart phones and wearables sensing devices - coupled with methodological developments in data science - have the potential to drive new and innovative behavioral applications that involve tools and platforms for continuous human monitoring. The goal is to develop a robust, intelligent software system that leverages individual level social sensing data to provide network level analytics of behavioral interactions for designing effective teams.

The first challenge (manage collection) is to create a social sensing platform to allow non-technical end-users to collect and manage data from a variety of digital and analog sensors by automatically configuring a scalable data system flexible enough to store variable datatypes stemming from a plethora of data sources. This include pre-processing vast amounts of noisy digital and sensor data-streams to distill key human performance meta-data. The second challenge (team-level diagnostics) is to design novel algorithms for data analysis which must include, but are not limited to, social network analysis of single graphs and knowledge-based multi-graphs; flow analysis to assess team collaborations and interactions; and individual-level behavioral pattern analysis with the capability to infer human states that can be aggregated to infer team-level states. Additional capabilities should incorporate the latest analytical capabilities based on language analysis to infer team context from communications and indicators of hierarchical positioning [5]. The third challenge (recommendation engine) should provide a means to run what-if scenarios addressing team management challenges, such as address the family of problems under the scope of team composition and team member replacement, and approaches to link team-level diagnostics to predictive outcome-based models of team performance. The fourth challenge (visualization) should provide team snapshots by creating scalable visualization techniques to allow the user to explore individual and team profile information; fluidly visualize multimodal network graphs over time and in response to key work-directed events or changes to the team context (e.g. attrition, new teammate); drill through graphs to uncover the underlying data; and show how team behavior patterns change over time (e.g. team structure).

The implemented system will have a small form factor that is multi-platform, scalable software. The system will provide the ability to choose multiple algorithms for analysis and recommendations based on user needs. Additionally, the graphical-user interface must be turnkey, with an easy to use interface for non-technical end-users. The system will contain a searchable database as well as modular and modifiable transparency with respect to the knowledge-based multi-graphs driving the recommendation engine. All stored data must retain available and relevant behavioral meta-data such as sender, receiver, date, time, geo-tags, and inferred individual and team-level states. The system should provide efficient analytical capabilities including the ability to create and customize diagnostic team profiles.

PHASE I: The Phase I effort will address the first two challenges (manage collection & team-level diagnostics) by developing and demonstrating a clearly defined approach to a social sensing framework to automatically capture social and collaborative team interactions in a variety of work-directed and organizational settings. A key data management challenge involves the aggregation and pre-processing of vast amounts of heterogeneous multi-scale, multi-level data. The social sensing framework will be designed to aggregate disparate data types from a variety of sources and be modular in design to accommodate frequent updates to APIs. A key requirement for a successful Phase I is an initial pass-through of multi-scale and multi-level data aggregation and the identification of social network metrics combined with algorithmic approaches to address a clearly defined framework of team-level diagnostics. The academic partner will focus on developing algorithmic approaches to model team composition and their interactions. The industry partner will focus on developing potential use-cases as well as a viable business plan to commercialize team analytics using a social sensing platform. This includes understanding customer needs and user requirements for developing a metric framework needed to effectively manage teams.

PHASE II: The Phase II effort will address the third and fourth challenges (visualization & recommendation engine) by concentrating on the design and development of analytical capabilities to provide a composite picture from multiple data sources and providing informative, scalable visualization capabilities of the underlying team-level analytics. A key consideration includes the design of privacy-preserving organizational social analysis system that uses social sensors to gather, crawl, and mine various types of data sources, potentially including individual email and instant message communications, calendars, the formal social structure (i.e. organizational chart) as well as individual role assignments, and data from wearables technology (from heart-rate to mobility to cameras). A key analytical challenge is that wearables and social sensing platforms not only produce vast data streams collected in natural settings over long periods of time, but the overriding context is dynamic, unpredictable, and perhaps even unknown. Contextual variables will be ascribed such as significant environmental events and changes to team composition. Phase II will develop multi-graph approaches that combine social network analytics with knowledge graphs to predict outcome-based measures of team performance. Specific Phase II milestones include the collection of a minimum of six weeks of longitudinal behavioral data from a variety of sources from a work-directed team and a demonstration of the key functional concepts derived from this dataset. The offeror must demonstrate a clear understanding of analytics relevant to military needs.

PHASE III DUAL USE APPLICATIONS: Phase III efforts will be directed toward refining a final deployable design with sophisticated, cross-platform GUI; incorporating design modifications based on results from the tests conducted during Phase II; the system should be hardened for security and protection of personally identifiable information (PII) and results by taking all appropriate measures to incorporate technical security of data collection, aggregation, and analytics; and improving engineering/form factors, equipment hardening, and manufacturing designs to meet U.S. Army CONOPS and end-user requirements.

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KEYWORDS: Team Science, Data-Driven Behavioral Analytics, Team Readiness, Human State Estimation Team Performance Assessment, Team Management, Knowledge Management

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| A18B-T009 | TITLE: Wavelet-Based Adaptive Antenna Systems |

TECHNOLOGY AREA(S): Electronics, Sensors

OBJECTIVE: Create a mathematical/numerical framework for the design, analysis and optimization of performance of multi-frequency antenna systems that can radiate vastly different frequency bands/waveforms and so simultaneously address diverse tasks, such as radar imaging and telecoms. Develop algorithms/software that implements these capabilities in military/commercial simulation applications and demonstrates feasibility of a small multi-frequency antenna by designing and building a hardware prototype.

DESCRIPTION: Use of multi-frequency antennas for emitting radio waves has obvious practical benefits as the same hardware can be used to accomplish different missions. Such systems have received substantial attention in recent years. They include various multiband antennas [1], antennas that allow different tasks to share the same frequency bandwidth by projecting signals onto the null space of an interference channel [2], and antennas that exploit signal fragmentation (e.g., wavelets) to create the desired waveform [3]. Compact multi-freq antennas offer the additional benefit of being easily mounted on a small vehicle or UAV. Wavelet-based antenna systems show promise of providing the unifying design, analysis, and optimization needed for these operationally useful multifunction antennas. Wavelet-based antenna systems radiate short EM pulses that are by nature wideband. But if a linear combination of such pulses is used to form the desired signal, then both long and short wave signals can be radiated from the same modest array of individual antenna elements since each pulse has finite duration so that a given array element can be reused. A linear combination of short pulses can yield a low-freq signal, which may be useful, e.g., for AM or FM communication, or other digital modulation formats (e.g. FSK, PSK, QAM), or longer wavelength radar applications (e.g. P-band SAR [4]). At the same time, these short pulses can also be combined into signals of much higher frequency that may be useful, e.g., for L-band SAR.

This project seeks computational methods to obtain the desired signal as a linear combination of pulses of various shapes in order to enable new multifunction antennas. For example, compactly supported wavelets are well known [5, pp. 215-287], being defined on finite intervals, having zero mean, and obeying an orthogonality relationship. Each wavelet, since it has zero mean, can in principle be radiated by an antenna. The use of multiple antennas radiating the properly selected wavelets (dilated and translated) can be combined to form the prescribed signal in the far field. A quasi-interpolation approach [6] or an approximate wavelet approach [7] can provide a simpler antenna structure. In the quasi-interpolation method, the desired function is expressed as a linear combination of translated, but otherwise identical, basis functions, each with zero mean. At a greater level of complexity, one can employ both translation and dilation for exact or approximate reconstruction. Applications of wavelets to radiation of the predetermined electromagnetic signals are discussed in [8] and [9].

We seek advances that leverage these tools from mathematical/numerical analysis. While operational requirements and system parameters are application-specific, the problems of designing small adaptive antennas have much in common. Foremost are considerations of energy efficiency. Radiation of long waves by small-size antennas will necessarily involve some destructive interference since generating a long wave composed of a sequence of short pulses will require that the spectral tails of those individual pulses cancel out. So there is a fundamental mathematical question of how to design constituent pulses to minimize power loss. Answering this will require ideas from Fourier analysis, wavelets, optimization, and other areas. Mathematical insight is needed for questions in antenna radiation patterns, i.e., in directivity. Achieving the ability to reduce or minimize power losses for both omnidirectional and direction-specific multi-freq antennas will lead to both theoretical advances for design tools, and will reduce the amount of required prototyping.

PHASE I: a) Survey existing designs and approaches for constructing multi-frequency antennas, review typical applications and regimes of interest, and identify relevant settings and parameters to demonstrate the feasibility of a universal analytic and engineering structure for their design and fabrication. One candidate is the use of wavelets and filters.
 b) Analyze and identify useful families of basis functions that can reconstruct a given signal (wavelets, truncated derivatives of the sinc function, etc) and that show promise of optimization.
 c) Develop a scheme for producing optimal linear combinations from the basis, assuming nearly isotropic (nondirectional) small antennas (small ratio of dipole to wavelength) are used in the far field. An appropriate figure of merit may be the ratio of total far field power divided by the input power.
 d) Implement the foregoing optimization scheme numerically and conduct the appropriate proof-of-concept computations.
 e) After the optimization scheme has been demonstrated, use to fabricate a prototype omnidirectional multi-frequency antenna.

PHASE II: a) The optimization technique from Phase I will be tested, validated, and implemented as a documented software package that can be shared or distributed.
 b) In the numerical work that seeks the best basis functions, demonstrate that the selected linear combinations reconstruct the square wave modulated sinusoids and square wave modulated chirps with minimal mean square error both computationally and in device tests.
 c) Since the basis functions are wideband, they may be radiated by directional antennas, and so a directional beam can be formed. Develop a computational scheme to optimize the basis function-antenna transfer function combination to maximize peak power radiation. First conduct the analysis for continuous wave (CW) operation.
 d) Incorporate the methodology of item c) into the software package of item a).
 e) Generalize the methodology described in item c) to other waveforms beyond CW, for example, frequency modulated continuous waves (FMCW) or linear chirps.
 f) Fabricate the nondirectional prototype antenna. Only a small number of antenna elements should be used (e.g., dipoles no more than 10 cm in length radiating pulses of approximately 1 ns in duration). Government is very interested in seeing the analysis and design package developed for fabrication.
 g) Develop optimal basis functions for directional antennas (eg, involving Vivaldi elements) using the computational methods of (a) and (d) above. Demonstrate success and utility of these methods, such as by fabricating a directional antenna, ideally with full width of 2-4 degrees when at half power.
 h) Prepare and make available software documentation of the developed package.
 i) Make available the software from items a) and d) to interested users in academia and industry under appropriate licensing agreements.

PHASE III DUAL USE APPLICATIONS: Results will be corroborated by prototype fabrication. This work will lead to significant speedups in the design time of military detection, imaging, surveillance, and communication systems, and will be equally useful in similar commercial applications. The analysis and numerical techniques developed under this topic will be made available as an aid in further advancement of this important new technology of multi-frequency antennas, e.g. to ARL-SEDD-Antenna Branch, CERDEC-STCD, Electronic-Warfare-oriented businesses, and others.

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KEYWORDS: basis function, signal fragmentation, wavelet, linear combination

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| A18B-T010 | TITLE: Mitigation of Ransomware |

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Create a highly effective end-to-end technology solution that mitigates the threats that ransomware poses to computer memory systems. By providing a more effective recovery from attacks, a successful solution will enhance the operational readiness and resiliency of Army and DoD information systems.

DESCRIPTION: Ransomware is malicious software (a.k.a. malware) that can lock a victim’s computer memory through cryptographic encryption to prevent access until a ransom is paid. Typically, ransomware adapts strong cryptographic algorithms to lock user files, making its extremely costly or nearly impossible to recover. It is estimated that ransomware has cost nearly $5 billion in damages worldwide in 2017 alone, and if left unmitigated, by 2019 will hit an enterprise every 14 seconds causing a projected total loss of $11.5 billion. Due to the potentially high risk of incurring data loss, ransomware poses an extreme threat to the Army and its overall operational readiness.

It is critical that we establish a comprehensive technology solution that can effectively mitigate the threat that ransomware may bring, and allows for effective recovery when critical data has been victimized. This should include the establishment of three important capabilities: 1) effective identification and detection of ransomware so that it could be disabled and eliminated before it is able to harm the system under attack. Recent advances in both static and dynamic analysis in conjunction with big data analytics provides a foundation to create advanced techniques that can identify potential ransomware with a high precision (high positive and low false negative rate), to allow effective countering against zero day attacks, 2) timely isolation and disabling of ransomware attacks so that suspicious binary code can be prevented from carrying out cryptographic operations that may lock victim’s data. New techniques that extends current on demand isolation techniques are expected. 3) given that some ransomware may eventually evade detection and quarantine, it is imperative that an effective and timely recovery capability that does not rely on regular file backups be created. Potential desired approaches might exploit data redundancy capabilities on physical drives, leverage garbage collection mechanisms within file systems, or use cryptographic means to recover lost data.

PHASE I: Propose and validate (via simulation and testing) a prototype detection and identification system for ransomware based on static and runtime patterns that leverage the existing large volume of malware detection research conducted over the last 20+ years. Big data analytics and new machine learning techniques may also help identify potential ransomware. Develop a prototype recovery method such that victim data could be recovered in minimal time. The solution must NOT rely on file backup mechanism.

PHASE II: Develop a fully deployable ransomware detection, mitigation and recovery system that can be used to protect a wide range of computing platforms (servers, storage systems, computers, and mobile devices, include USB drive or other portable storage devices). Demonstrate efficacy of the system in terms of 1) accuracy in ransomware identification and detection, and effectiveness of mitigation; 2) timely recovery of victim data; 3) minimum impact to system performance. Solutions should also provide maximum user transparency so that an average user’s experience will not be negatively impacted.

PHASE III DUAL USE APPLICATIONS: Further develop and mature an actual system prototype and validate its performance through demonstration in an operationally relevant environment. Define, finalize, and execute the transition and commercialization plans.

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KEYWORDS: ransomware, detection, mitigation, data recovery, system assurance

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| A18B-T011 | TITLE: Software Tools for Scalable Quantum Validation and Verification |

TECHNOLOGY AREA(S): Electronics, Sensors

OBJECTIVE: Design and develop a comprehensive set of software tools to significantly accelerate the development and validate the performance of prototype multi-qubit quantum systems in the emerging quantum computing industry.

DESCRIPTION: Considerable advances have been made in developing and demonstrating high-fidelity one and two-qubit operations in a multi-qubit system. These advances begin to demonstrate key elements of a quantum information processing system. As the complexity of these demonstrations increase, the task of benchmarking performance of the systems becomes very challenging. A series of techniques have been developed, broadly termed "quantum computing validation & verification (QCVV). Incorporation of these techniques in experiments and hardware development has been difficult because of the subject matter expertise required. With growing DoD and commercial interest in quantum information processing, there is a compelling need and anticipated demand for robust software tools, based on QCVV techniques, to benchmark the performance of multi-qubit systems beyond current experimental techniques such as tomography. Ideally, such software tools would provide ease-of-use and fool-proofing for essential techniques to accelerate design cycles, validate performance at gate level, and certify quantum computer output at the whole circuit level. The software tools would also provide standardization, reliability and transparency regarding characterization of hardware performance. Desired features of the software tools include:
(i) software implementation of essential and scalable tools that diagnose and optimize the performance of quantum gates and quantum circuits (both at physical and logical level).
(ii) development and software implementation of scalable diagnostics for determining rigorous confidence estimates on the output of an arbitrary quantum computation over arbitrarily many quantum bits (at either physical or logical level) by bounding deviations from the target output based on a family of scalable diagnostics, and
(iii) hardware (control-system) interfaces/implementations of the above software tools for high-performance multi-qubit systems.

PHASE I: Design and develop a software framework that allows incorporation of state-of-the-art QCVV techniques and establish feasibility of operating the software with high-performance multi-qubit systems. Establish that the software framework is scalable to multi-qubit systems of tens of qubits.

PHASE II: Develop and demonstrate a complete scalable software tool package that can operate at the physical and logical qubit level and with high-performance multi-qubit systems. The tool package would desirably include:
1. A set of fully scalable tune-up routines for optimizing gate performance.
2. A set of fully scalable diagnostic routines providing a complete set of canonical performance parameters for multi-qubit quantum processors.
3. A rigorous and tight bound certifying the performance of quantum information processing circuits with large numbers of qubits.
Demonstrate overall functioning, utility, versatility, and ease-of-use of the software tools and framework by integrating into an existing quantum information processing experiment.

PHASE III DUAL USE APPLICATIONS: The software tool developed here has impact on the successful demonstration of quantum information processing. In addition to critical national security applications, quantum information processing is anticipated to have an impact on commercial applications involving hard computational problems such as optimization, routing, planning and scheduling, among others. Research universities, DoD Laboratories, National Laboratories, and DoD contractors participate in quantum information processing research efforts that would require software tools described in this topic to develop and test their systems. Commercial companies are aggressively pursuing small scale processors whose development and testing will also require these software tools. The tools could also evolve to apply to a broader class of quantum technology for sensors and metrology being developed by DoD entities and commercial companies. Such a robust software tool is expected to have wide use by these quantum technology developers.

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KEYWORDS: qubit verification, qubit validation, qubit tune-up, qubit benchmarking, quantum computing

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| A18B-T012 | TITLE: Hybrid Nano-Bio-Electronic Odor Detector |

TECHNOLOGY AREA(S): Chemical/Biological Defense

OBJECTIVE: Develop a hybrid odor detector incorporating genetically modified mammalian olfactory receptors interfaced to complementary metal-oxide-semiconductor (CMOS) nanoelectronic integrated circuits to demonstrate detection of volatile environmental and/or biological odorants from complex mixtures.

DESCRIPTION: The Army has an urgent need for cost-effective odor sensors, as evidenced by the focus within the Army Research Laboratory Materials Research Campaign to combine novel biological materials with inorganic devices to sense chemical and biological agents. Electronic nose technology shows promise and has resulted in devices with higher specificity, sensitivity and greater ease of use (Fitzgerald et al, 2017). However, artificial noses still do not possess the dynamic range and selectivity of the mammalian nose, nor show sufficient sensor stability for evaluating sample gases containing complex mixtures of molecules in very low concentrations (Berna et al, 2009). Novel olfactory biosensing approaches may overcome these technological challenges by integrating the specificity and sensitivity of biological olfactory sensor-ligand interactions with engineered sensor platforms (Lee and Park, 2010).

The mammalian olfactory system utilizes sensitive odorant receptors, expressed at the surface of cilia on chemosensory olfactory neurons to detect and discriminate thousands of low-molecular-weight organic compounds with diverse chemical structures and properties. Each cilia contains receptors that recognize multiple odorants, and each odorant binds to multiple receptors. When sufficient numbers of odor molecules interact with olfactory receptors a combinatorial code of spike activity from ciliated olfactory neurons is processed by the olfactory pathway of the brain. However, advances in olfactory bio-electronic sensing have demonstrated proof-of-concept that isolated olfactory sensory neurons and receptor components can actively transduce information about specific volatile odorants to engineered sensors (reviewed in Lee and Park, 2010).

Recent accomplishments in combining olfactory sensory elements with CMOS nanoelectronic integrated circuit technology opens the door to development of a commercially viable nano-bio-electronic olfactory detector (Chaudhuri et al, 2016). However, several limitations must be addressed by this STTR to achieve specific field-based odor detection required by the Army. Rigorous culture environment requirements for tissues and cells, the relative lack of stability of olfactory cells under real-world conditions and lack of transportability all pose immediate barriers that must be overcome (Glatz & Hill, 2011). Unique and powerful insight into innovative approaches toward fabrication of next-generation bio-hybrid odor detection systems is now available through recent successes in genetic engineering of olfactory receptors (D'Hulst et al, 2016) and hybrid bio-olfactory electronic chip development (Chaudhuri et al, 2016).

 The ultimate goal of this STTR is to leverage advances from olfactory biosensing and define a new class of bio-nose-on-a-chip sensors that show robust, scalable and reproducibly sensitive olfactory receptor transduction. Ultimately, multiplexed signals from an array of specified olfactory receptors from isolated cilia will be coupled with a biologically-inspired signal processing strategy for classification of multiple odorants from a complex real-world mixture sample. When produced by available standard molecular biology, cell physiology and semiconductor manufacturing techniques they provide an inexpensive and sensitive device for DoD environmental and biological monitoring of specific low concentration odorants in operational environments. Not only could such a tool be used for actual sensing strategies, it offers a tremendous research tool to pin down olfactory ligand-receptor interactions that still have not been able to be determined.

PHASE I: Determine technical feasibility of a CMOS bio-nanoelectronic odor detector using biological olfactory receptors as the sensor front-end. The Phase I effort should benchmark immobilization of functional olfactory receptor elements (tissue or cell-based), in-silico determination of optical (fluorescent), electrical and/or 2nd messenger response limits to guide optimal nanoelectronics integration in Phase II, and characterization of odorant detection specificity by the prototype sensor. The Phase I effort should also determine the technical feasibility for, ultimate, longevity of the biological components of the sensor beyond six months, by establishing a reliable de-ciliation method for preserving and isolating olfactory receptor activity. Nanoelectronic mobilization methods should be defined in Phase I.

PHASE II: Develop, demonstrate and validate, a prototypical bio-electronic olfactory sensor based on criteria established from the Phase I feasibility parameters. Prototypes should be demonstrated for tissue or cellular-based olfactory sensors to benchmark isolated cilia-based sensors. The performance of the sensor should be fully evaluated in terms of sensitivity, selectivity, and dynamic range. The project needs to deliver theoretical/experimental results that provide guidance regarding how the sensors can be designed and fabricated for a range of applications that meet ease of maintenance, storage and long shelf life. The new system will process and interpret biological signals directly for classification by on-chip biologically-inspired signal processing methods. Establish sensing requirements and approaches to improve longevity and robustness of the interface and scalability of the bio-hybrid sensor front-end.

PHASE III DUAL USE APPLICATIONS: The Phase III work should demonstrate odor detection specificity and response operating conditions of the bio-nano-electronic olfactory sensor for sensitive detection and, ultimately, expansion to airborne sampling capabilities. Emphasis will be placed upon prototype performance parameters, longevity and scalability of the biological sensor front end. Phase III deliverables will include: (1) A working prototype of the bio-nose-on-a-chip technology (2) test data on its performance and (3) specifications for potential to detect multiple odorants simultaneously in complex Army-relevant samples with high sensitivity and selectivity.

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KEYWORDS: olfaction, nose-on-a-chip, biosensor

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| A18B-T013 | TITLE: Disablement of Vehicles and/or Remote Weapon Stations in an Urban Environment |

TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Develop a system that is safe enough to be operated among a civilian population that is capable of disabling critical components of opposition ground vehicles.

DESCRIPTION: The sociopolitical ramifications of collateral damage, especially the type of damage that can be inflicted with traditional anti-armor assets have made it increasingly difficult for the dismounted soldier to engage lightly armor vehicles. New armored vehicles are likewise much more likely to be equipped with remote weapon stations (RWS) to provide the "teeth" for these and these RWS are often highly instrumented to provide vision, range finding as well as weapon stabilization. If the instrumentation can be blinded or the stabilization destroyed, they become far less dangerous to the dismounted soldier and the civilian population as a whole. If the entire electronics of the RWS can be disrupted, even basic traversing and firing functions become disabled.

Additionally there are static high value targets that represent a unique concern to the local civil population such as surface-air missiles, guns and associated radar and tracking equipment that is placed in or near civilian housing, hospitals, schools, mosques or other structures that would have strong negative sociopolitical, ramifications should they be attacked in a normal physical manner.

The ability to disable these targets in a manner that provides for very low collateral damage, with respect to civilian loss of life, would increase the effectiveness of the dismounted soldier in the modern, news-centric, politically-charged environment.

Soldier borne systems that can affect these or other "soft-kill" mechanisms are of interest. Most importantly are systems that provide these mechanisms at a distance or can be launched and function at a distance that provides the dismounted soldier with an appreciable level of remoteness (i.e., 100+meters). The system must be able to be deployed by a single dismounted soldier in a MOUT environment.

PHASE I: Explore and evaluate multiple non-kinetic-kill mechanisms that can provide either a mobility kill, defeat of a remote weapon station with a low collateral damage mechanism for leveling the playing field against mechanized assets. Develop a preliminary size, weight, and cost criteria for the given mechanism. Systems that require thousands of dollars per round (when produced in quantity) are considered beyond the scope of this project. The mechanism must be easy to deploy by an individual soldier and inexpensive enough that dismounted soldier feel free to deploy them.

Concepts may either require contact or may function at a proximity are considered viable providing they can a similar level of defeat. A purely proximity system relying on strong electromagnetic fields, for example, should be able to demonstrate field strengths on the order of 1kV/m (objective) or 50V/m (threshold) as an electric field. While lower field strengths will easily damage or destroy sensitive electronics such as radio receivers or GPS/GLONASS (Russia's version of GPS) receivers, the goal is to disable the underlying vehicle and/or its remote weapon station, sensors and the vehicles engine control unit (if present). While contact systems would need lower field strengths, mechanism to mitigate shock hazards need to be addressed.

Show that the proposed mechanism can function, and is operationally relevant for the deployed dismounted soldier. The proposed mechanism must be able to be delivered in a payload weighing less than five pounds, and be effective in disabling or disrupting the intended component of the mechanized system in under 5 minutes.

Identify an existing fielded system that could be used for the deployment of the soft-kill system. In order to reduce the logistical burden of fielding such a soft-kill system, it is imperative to build on systems already deployed or are expected to be deployed in the near future. An engineering estimate in practical range of deployment should likewise be provided.

PHASE II: Down select the method/modality of deployment based on the work from Phase 1 as well as feedback from the customers. Once again, the ability to use or build on currently deployed systems is of primary importance.

Develop bench prototype of the most promising non-kinetic defeat mechanisms, proximity or contact. Of special interest, but not required, are those mechanisms that that can be used synergistically for simultaneous deployment or those whose mode can be selected prior to deployment in order to maximize their utility against various armored vehicles (ie. Light vehicle vs structure). Demonstrate in a controlled environment those mechanisms and how they would disable relevant critical components. It is imperative that these mechanism are not viewed as lethal to bystanders save for concerns of an accidental kinetic effect from the deployment itself. Evaluate the mechanism's utility versus its propensity for accidental collateral (property) damage.

Demonstrate a clear development path that would permit the bench prototype to convert into a system that can be deployed at range. For proximity based systems, develop mechanisms that focus or direct the effect at the particular target and reduce the accidental damage to civilian infrastructure (objective). All systems must be viewed as a non-lethal device (threshold) save for actual unintentional kinetic effects prior to functioning. Mechanisms to reduce the probability of an unintentional kinetic injury or fatality should be explored, e.g. drogue chutes.

Using surrogate systems that are anticipated to have the same bulk/mass of the idealized system and demonstrate that they can be deployed in an accurate manner.

PHASE III DUAL USE APPLICATIONS: Work with both the Department of Defense (DoD) and civilian law enforcement agencies and the National Institute of Justice (NIJ) to develop guidelines for use and provide further guidance in areas to market the soft-kill system. Develop an understanding of the variations in needs between military and CLEO customers. Incorporate these expanded requirements into a system that can be commercialized leveraging both DoD, NIJ and private funding opportunities. Demonstrate live fire deployments of the actual system. Work with various customers inside the DoD to insure that the system can be deployed inside the existing Concept of Operations (CONOPS) or without an aggressive procedural change.

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KEYWORDS: Dismounted soldier protection, body armor, electrical systems disruption, vehicle stopper, military operations in urban terrain, cyber-physical systems, electrical signal conditioning, chemical signal conditioning, graphite, tribology

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| A18B-T014 | TITLE: Robust High-Performance Laser Sources for Scalable Quantum Technology |

TECHNOLOGY AREA(S): Electronics, Sensors

OBJECTIVE: Design and development of robust, long lifetime, high-performance continuous wavelength (CW) laser sources that would enable high-fidelity multi-qubit trapped ion systems for scalable quantum computing, networking, and broader sensor and precision measurement technology.

DESCRIPTION: Trapped ions systems represent one of the very promising avenues for scalable quantum systems technology and have demonstrated high-fidelity multi-qubit operations. Laboratory-based laser systems that enable current qubit operations are typically an assortment of Commercial-off-the-shelf (COTS) and home-built lasers, optics, and control electronics. These laser systems can occupy a significant fraction of the researchers' time, attention, and resources in dealing with beam misalignment, power instabilities, and frequency locking/re-locking. Scalability is limited by laser system reliability. With growing DoD and commercial interest in quantum technology, there is a compelling need and anticipated demand for COTS robust compact laser sources to enable scalability. Ideally, such laser systems would deliver intensity- and frequency-stable light, automatically engage locks, detect and correct for system failures, and have telecommunications industry-like reliability. These systems must also be agile and controllable, providing flexibility to prepare, address, and read-out the qubits in order to operate the qubit system with high fidelity. Developing such capability and reliability will require a multifaceted systems approach.

Potential development areas include:
 (a) A common laser architecture/package that can span the full spectrum of ion wavelengths with sub-100 kHz linewidths.
 (b) A fixed, mechanically stable optics bench that eliminates external tuning (e.g. a grating).
 (c) A sealed laser package free of contaminants that can prematurely age the laser.
 (d) Electronics and software to automatically acquire and engage atomic and cavity locks.
 (e) More compact laser heads and control electronics.

PHASE I: For a candidate ion(s), determine the laser requirements (such as power, linewidth, lifetime, locking bandwidth, among others) for all relevant transitions. Verify requirements with a leading research group developing the candidate ion system. Some demonstrated and preferable ion systems are Ba, Be, Ca, Sr, and Yb. Design a laser or modify an existing design to meet the requirements of the candidate ion system. Validate critical design features and requirements through simulations or proof-of-principle benchtop tests.

PHASE II: Build prototype laser heads and electronics. Demonstrate design versatility by building lasers at the relevant wavelength extremes (e.g. for Yb+, 369 nm and 935 nm). Characterize the full laser performance and lifetime. Develop electronics and software that automate and extend laser locking for atoms and optical cavities. Demonstrate significant performance and reliability improvements over state-of-the-art by integrating and testing the laser/controller into an existing ion trap experiment.

PHASE III DUAL USE APPLICATIONS: The technology developed here has impact on the successful demonstration of quantum information processing. In addition to critical national security applications, quantum information processing is anticipated to have an impact on commercial applications involving hard computational problems such as optimization, routing, planning and scheduling. Stable, narrow-linewidth lasers are also critical for optical atomic clocks and atomic inertial sensors. These devices can precisely determine position, orientation, and timing in GPS-denied environments.

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KEYWORDS: UV laser sources, blue laser sources, trapped-ion quantum computing, atomic clocks, quantum sensors.

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| A18B-T015 | TITLE: Microporous Flexible Electrodes for Lithium Metal Secondary Batteries |

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Develop and characterize flexible microporous electrodes for lithium metal secondary batteries.

DESCRIPTION: The DoD has need for inherently safe energy storage devices with improved high power, high energy density, and low temperature performance to reduce dismounted soldier burden. Lithium metal batteries offer an opportunity to increase energy density because lithium has the highest theoretical capacity (3,860 mAh/g) and lowest electrochemical potential (3.04 V). However, the use of lithium metal has posed challenges such as limited cycle life and the propensity to form lithium metal dendrites which can reduce capacity and lead to short circuits. In addition, the presence of lithium metal, with its high reactivity, poses a concern if the battery is compromised and the lithium is exposed to the atmosphere. Flexible microporous electrodes have been predicted to reduce dendrite growth due to confinement of lithium in individual pores while simultaneously increasing charge/discharge rates due to the high surface area. Advantages derived from the use of microporous electrodes include: high energy density, fast charge and discharge rates, and long cycle life. In addition, depending upon the selection of microporous support material the batteries could also be flexible and containment of lithium in individual micropores could increase safety. This effort will develop and characterize flexible microporous electrodes to enable conformal, safe, lithium metal batteries.

PHASE I: Demonstrate and optimize flexible microporous electrodes with lithium metal electrodes. Determine structure property relationships between pore size and distribution and their impacts on electrochemical performance including formation of dendrites and half cell cycle life. Evaluate electrolyte formulations to ensure support material compatibility. Prepare laboratory half cells, perform high power and specific energy testing, and identify degradation processes. Demonstrate results that indicate that a specific energy >350 Wh/kg and improved life cycle performance of >150 cycles with 80% capacity retention are possible using flexible microporous electrodes.

PHASE II: Extend microporous electrode technology to cathode and evaluate a at least 3 cathode materials. Evaluate cathode half cells to optimize electrochemical properties. Determine structure property relationships between pore size and distribution and their impacts on electrochemical performance. Continue optimization of lithium metal anodes. Prepare complete batteries (over 1000mAh), perform high power and specific energy testing, and identify degradation processes. Demonstrate results with a specific energy >400 Wh/kg and improved life cycle performance of >300 cycles with >90% capacity retention.

PHASE III DUAL USE APPLICATIONS: Development of devices for both civilian and DoD use. There are many electronic devices used in the military and civilian communities that would benefit from increased energy storage. Portable electronics, hybrid vehicles, etc. performance will be improved if safe lithium metal secondary batteries with high cycle are developed.

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KEYWORDS: Lithium Metal Battery, Porous Electrodes, Secondary Battery

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| A18B-T016 | TITLE: Cell-Free Screening System for Genetically-Derived Small Molecule Biosensors |

TECHNOLOGY AREA(S): Electronics, Sensors

OBJECTIVE: Develop a cell-free system to rapidly identify biosensors to small molecules of DoD interest, which can then be further evolved and implemented in biologically-derived products (e.g., paper-based cell-free sensors, engineered microbes) to protect the Warfighter.

DESCRIPTION: Nature has evolved over millennia an ability to sense and respond to nearly any environmental input possible. Much more recently, the emerging field of synthetic biology has begun to repurpose the toolbox of nature towards engineering applications. Of particular relevance here, biosensors utilizing biological detection methods are increasingly being pursued as technologies to protect the Warfighter. For example, paper-based cell-free sensors are highly-portable products that can detect threats such as Zika and Ebola with high-efficiency [1], [2]. Microbes can also be engineered to detect environmental chemicals such as naphthalene and arsenite [3]. There is strong Army interest to transition these new technologies from the laboratory to the field [4].

A technical limitation, however, is the lack of well-characterized, specific, and adaptable biosensors available to convert environmental signals into biological signals for downstream processing. This dearth of inputs currently hamstrings products such as paper-based cell-free sensors that have high potential as highly-fieldable, broad-spectrum threat detection technologies that could protect the Warfighter. Since nature has evolved biosensors to detect nearly every small molecule (for example, in one study 95% of antibiotics could not only be detected, but also degraded by bacteria [7]), harnessing this detection power for threats of Army interest is highly desired. While it is known that cells naturally respond to broad-spectrum analytes, the specific mechanisms remain obscure outside of a handful of model biosensors; thus, identification of novel biosensors requires either identification of natural sensors and downstream engineering [5] or computational design and experimental validation [6]. Methods to streamline the process of identification and optimization of novel biosensors would greatly accelerate the development of these new technologies and ultimately provide a new generation of sensing technologies to the Warfighter.

The objective of this topic is to develop a rapid cell-free screening system capable of biosensor discovery for a particular small molecule target in two months or less. These biosensors must be implementable in a molecular circuit to convert chemical signals to downstream biological signals. Of particular interest are protein-based transcription factors that transduce a signal via promoter regulation in response to the presence of the small molecule of interest; however, other mechanisms such as RNA-mediated regulation or translation-level control will be considered. In final form, the system must be capable of producing functional biosensors to multiple DoD-supplied small molecules.

PHASE I: Define a cell-free system that is able to take as input small molecules and provide as output a biological response, e.g. a biological protein effector, effector target promoter, and output reporter expression. Demonstrate the system's effectiveness with 5 model small molecule targets. For each novel small molecule, demonstrate the system's ability to test at least 8 unique protein effectors and effector targets experimentally in the cell-free system. The Phase I effort should demonstrate proof-of-principle of the system and identify a path to scaling up to high throughput performance.

PHASE II: Demonstrate the cell-free system's effectiveness by identifying biosensors for at least 10 small molecules of DoD interest that have currently no known biological effector. For each novel small molecule, demonstrate the system's ability to test at least 96 unique protein effectors and effector targets experimentally in the cell-free system. Collaborate with DoD scientists to identify at least 2 target molecules of interest, and demonstrate a turnaround from molecule identification to protein effector and effector target of 2 months or less.

PHASE III DUAL USE APPLICATIONS: The Phase III work will produce a scalable solution for identifying biosensors to arbitrary naturally-derived small molecules, with dual-use applications in government-relevant products (e.g. sensors, engineered microbes) and in industrial products (e.g. bio-based chemical development).

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KEYWORDS: biosensors, synthetic biology, high-throughput screening, paper-based sensors, metabolic engineering, cell-free systems

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| A18B-T017 | TITLE: Millimeter-wave modulators for sparse aperture imagers |

TECHNOLOGY AREA(S): Electronics, Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the Announcement.

OBJECTIVE: Develop a modulator that up-converts millimeter wave (MMW) signals to optical wavelengths. This modulator would enable sparse aperture MMW imagers based on optical up-conversion to be developed using inexpensive focal plane arrays (FPA), allowing the fabrication affordable imaging systems intended for ground vehicles.

DESCRIPTION: Degraded Visual Environments (DVE) are a leading contributor of accidents and reduce Soldier operational effectiveness. Accidents during rotorcraft landings and reduced OPTEMPO of ground vehicles are two common drawbacks of operating under DVEs. Degraded environmental conditions can be mitigated using proper sensing that allows increased situational awareness, such as MMW imagers. Recent developments have shown that a phased array of MMW detectors can be used to penetrate severely degraded environments, while partially mitigating some of the issues of size, weight, and power (SWAP) typical of MMW imagers. The described technique allows designs to be scaled to higher or lower resolution by cleverly adjusting the array distribution, without significantly altering the remaining system components.

This STTR seeks university research to develop a novel MMW-based sensor which penetrates dust, fog, and smoke. The sensor output will be fused with a conventional IR sensor to provide enhanced driver visualization. The ultimate goal of this effort is to create a dual-mode imaging system that includes a high-resolution LWIR sensor coupled with a low-resolution, but with high obscurant penetration, MMW sensor, that will provide cues to obstacles and hazards at ground level. The designed system should be capable of operating at video rates and have a horizontal field of view of at least 20 degrees. The MMW sensor will detect, though not necessarily recognize or identify, obscured targets that are not sensed by the LWIR imager. A combination of both sensing modalities will provide sufficient situational awareness to maneuver ground vehicles under most degraded conditions. The purpose of this STTR is to solicit affordable, novel MMW sensing approaches that provide enhanced obscurant penetration over conventional LWIR images. The full scope of the effort will demonstrate real-time fusion of the two modes. The scalability of this approach would also allow developing systems that can benefit other services and civilian applications.

PHASE I: Design and demonstrate operation of a MMW modulator concept that can be used on a sparse aperture MMW imager. Build a small array, between 3 and 10 elements, to demonstrate operation of this modulator.

PHASE II: Provide a trade-off study for resolution and array dimensions. Build and demonstrate a functioning imaging system based on the approach developed in Phase I. A path for fusion with a LWIR sensor must be provided.

PHASE III DUAL USE APPLICATIONS: Build and demonstrate a field deployable system on a relevant environment. Provide imagery of fused MMW and LWIR sensors.

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KEYWORDS: DVE, Degraded Visual Environments, RF, MMW, Up-conversion, RF-Photonics, Modulators, Millimeter-Wave, LWIR, Multi-spectral imaging, Sensors

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| A18B-T018 | TITLE: Rapid Prototyped 3D Printed Filters |

TECHNOLOGY AREA(S): Chemical/Biological Defense

OBJECTIVE: The objective of this topic is to develop novel filters/filter concepts using rapid prototyping and 3D printing technologies. Specifically, the filter will augment current general purpose respirators by snapping on to the top of current filter. This extra filter will either provide enhanced protection against toxic industrial chemicals (TICs), aerosols, or a combination of each.

DESCRIPTION: Currently fielded U.S. Military filters containing ASZM-T carbon provide excellent protection against a wide range of chemicals. However, additional protection is often warranted against toxic industrial chemicals such as ammonia, nitrogen dioxide, hydrogen sulfide, and sulfur dioxide. Furthermore, current filters provide excellent protection against aerosols, but fail to detoxify chemical warfare agents. Using additive manufacturing (aka 3D printing), a snap-on filter will be developed that enhances the protection against TICs, CWAs, and/or aerosols. The technology should be able to fit onto current military filters such as the C2A1, M53 General Purpose Filter, and/or the M61 filter on the Joint Service General Purpose Mask. The add-on filter may utilize novel sorbent such as metal-organic frameworks (MOFs), metal oxides, and/or polymers of intrinsic microporosity (PIMs). The snap-on filter itself may be adsorptive and utilize PIMs or other porous polymers.

Current Status: Over the past decade, 3D printing has maturing from a novelty to systems that are commercially available for the average home. Thus, systems can be utilized to manufacture on-demand items such as filters that focus augmentation of protection against specific chemicals. Parts can be printed to house sorbents or HEPA-type aerosol filtration media. Novel aerosol removal media that detoxifies CWAs is also available, such as electrospun nanofibers incorporating metal-organic frameworks or metal oxides.

PHASE I: Fabricate approximately 10 prototype snap-on filters (multiple concepts are acceptable) using 3D printing. Establish initial protection correlations such as enhanced chemical or aerosol protection. If the focus is on an “active” HEPA that detoxifies CWAs, show initial simulant reactivity data. Provide prototypes to ECBC for initial testing.

PHASE II: Print 100+ filters using additive manufacturing. Determine full performance of system and conduct ruggedness testing to ensure materials of construction are adequate to survive battlefield and transport conditions.

PHASE III DUAL USE APPLICATIONS: Identify additional military and non-military applications for use of materials. Work with Federal Laboratories (e.g. U.S. Army Edgewood Chemical Biological Center) to develop military filter concepts. Potential dual-use applications include, but are not limited to, First Responders, industrial plants, etc.

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KEYWORDS: 3D printing, additive manufacturing, filter, carbon, aerosol

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| A18B-T019 | TITLE: Novel Manufacturing Techniques for Polymer/Metal-Organic Framework Systems |

TECHNOLOGY AREA(S): Chemical/Biological Defense

OBJECTIVE: The two objectives of this topic are (1) to develop novel methods/techniques for integrating active nanostructures such as metal-organic frameworks (MOFs) into polymer-based systems, and (2) to assess new materials solutions for enhanced protective ensembles such as novel filter/mask designs and reactive suit technologies. Active nanostructures may include, but are not limited to, materials such as MOFs, zeolitic imidazolate frameworks (ZIFs), porous organic polymers (POPs), polymers of intrinsic microporosity (PIMs), metal oxyhydroxides (e.g., Zr(OH)4), etc. Materials solutions should focus on adsorptivity and reactivity against toxic chemicals such as nerve agents (e.g. soman, VX, etc.) and toxic industrial chemicals (e.g. ammonia, chlorine, sulfur dioxide, hydrogen sulfide, etc.). The end state of the program should be a scalable method for producing technologies such that sufficient material is available for advanced testing against threat compounds.

DESCRIPTION: Metal-organic frameworks and nanoactive metal oxyhydroxides have shown promise for detoxifying chemical warfare agents and toxic industrial chemicals [1-4]. One challenge has been integration of these materials into functional forms for use in filters and suits. Of particular interest are composites of porous nanomaterial with polymers and fibers. Over the past several years, atomic layer deposition has been used to coat fibers with a metal oxide which is subsequently used to nucleate and grow MOFs directly onto the fiber [5-7].This technique provides excellent MOF growth, but is difficult and expensive to scale. Other methods such as electrospinning have been used with mixed results [8, 9]. This effort seeks to develop large composites from active particles and polymers using alternative approaches to atomic layer deposition (ALD) that retain activity of the underlying nanomaterial once integrated into/onto the polymer. Ultimately, successful technologies could lead to protection commensurate with current protection equipment while reducing burden by an order of magnitude.

PHASE I: Demonstrate the ability to fabricate polymer/nanomaterial composites in square foot swatches. Provide materials to ECBC that are robust (do not shed particles) and are active towards toxic chemicals. Initial demonstrations may focus on one specific toxic chemical (e.g. chlorine) or a group of chemicals (e.g. acid gases, nerve agents, etc.).

PHASE II: Scale the process to larger quantities that are amenable to full scale production, such as 30 inch roll-to-roll processes. Deliver both composite fabrics and potential concepts for novel filters and suits. Concepts should focus on integrated textiles that offer aerosol and chemical protection.

PHASE III DUAL USE APPLICATIONS: Identify additional military and non-military applications for use of materials. Develop and implement strategies for reducing cost to compete with activated, impregnated carbon fabrics. Incorporate materials into other forms. Work with Federal Laboratories (e.g. U.S. Army Edgewood Chemical Biological Center) to develop military filter concepts, and identify companies with respiratory protection programs (e.g. 3M, Scott, Avon etc.) to transition materials for industrial and First Responder applications. Potential dual-use applications include, but are not limited to, industrial filter materials, escape respirators, etc.

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KEYWORDS: Metal-organic framework, polymer, fabric, filter, protective suit

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| A18B-T020 | TITLE: Sample Preparation Free Consumables for Ultra-Sensitive Chemical and Biological Detection from Complex Environmental and Clinical Matrices Compatible for Paper Spray Ionization Mass Spectrometry |

TECHNOLOGY AREA(S): Chemical/Biological Defense

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the Announcement.

OBJECTIVE: Develop a new line of paper spray consumables when can be leveraged for the direct capture and analysis of aerosols and vapors. Additionally, proposers should also develop a paper spray cartridge with an integrated affinity enrichment column for both small molecules and macromolecules (ie. proteins). Together these products would significantly expand paper spray mass spectrometry's utility for the direct analysis of chemical and biological threats in complex backgrounds without any sample preparation. Other than miniaturizing mass spectrometers, this is a crucial component for moving mass spectrometry-based identification into the field.

DESCRIPTION: Paper spray (PS) is an ambient ionization technique that allows for direct sampling with little to no sample preparation and rapid mass spectrometry (MS) analysis1. Samples are collected or deposited directly onto the paper substrate from biological and environmental sources and analyzed by MS without the need for desorption/extraction2-3. Currently, PS-MS has been reported to analyze CWA simulants and CWA hydrolysis products4 in biological matrices, as well as food and environmental samples containing pesticides and herbicides5-6, which have chemical similarities to CWAs. More recently, PS-MS was used to directly capture and analyze of aerosolized CWA simulants of G-series nerve agents (e.g., sarin, soman in both laboratory and field)7. Ultimately, the limits of detection using this approach were reduced to levels comparable to current worker population limits of 1x10-6 mg/m3 after just 2 minutes of sample collection. To perform all of this work, rapid prototypes were developed using 3D printing technologies. Although these approaches proved to be successful, additional design changes and materials must be developed to diversify and strengthen this new application of PS-MS.

Paper spray ionization can also be used for monitoring toxic industrial chemicals (TICs) and toxic industrial materials (TIMs). Given the recent problems associated with the highly fluorinated compounds commonly found in firefighting foams such as perfluorooctane sulfonic acid (PFOS), it is important to have the ability to rapidly screen water sources for these persistent-highly water soluble carcinogens. Screening will be a very important factor when prioritizing clean-up efforts. In many places where these foams were heavily used for training exercises they can be found at levels 20X higher than the safe limits established by the Environmental Protection Agency (EPA). Paper spray ionization in its current form is amenable for rapid screening of these types of compounds, but the commercial off the shelf (COTS) system currently available is not able to detect the low level concentrations (~80 pg/mL) established by the EPA. Therefore, there is a need to develop a cartridge that can enrich for these compounds as well as other small molecules for rapid screening purposes.

In addition to adding the ability to enrich for small molecules, there is a need to enrich for biological molecules from complex backgrounds such as food, soil, water, blood, and urine. For this applications the primary focus should be for the detection of proteinaceous toxins such as ricin, abrin, or botulinum toxin. Very recently, there have been several examples demonstrating that PS-MS can be used to detect this class of molecules (proteins) by utilizing a novel alternative substrate composed of polyethylene coated with carbon nanotubes. As such, the proposers should develop an enrichment device so that affinity reagents (antibodies and/or molecularly imprinted polymers) can be integrated into the current COTS form factor for the enrichment of toxins of military interest. The design should also be easily modified to incorporate other affinity reagents to biological targets of military interest including viruses and bacteria.

PHASE I: During phase I, performers will provide designs and functional prototypes of each of the paper spray devices to address the following:
1. Aerosol/Vapor collection:
This device should be designed as two distinct components: the air-handling unit and the consumable paper cartridge. This consumable should easily adapt to the air-handler and should be designed so that the sampled air can be directed through a substrate of interest.
2. Small Molecule Enrichment:
This apparatus should be developed so that a larger than normal sample volume can be pre-concentrated onto a column (e.g. SPE) and then eluted onto the paper substrate for ionization.
3. Targeted Protein Enrichment

This apparatus should be developed so that a larger than normal sample volume can be pre-concentrated onto an affinity column to enrich for proteins of interest for analysis by paper spray. Additionally, novel/proven substrates that are amendable for PS-MS protein ionization should be incorporated.

PHASE II: Candidates that are awarded a Phase II proposal shall further develop each consumable into a pre-production prototype which MUST be rigorously tested for reproducibility in a laboratory environment. Chemicals and proteins which will be tested for reproducibility and limits of detection should be identified within the Phase II proposal, but proposers should be amenable to suggestions from the technical chief. Prototypes should be made with mass spec friendly materials that have little to no interfering chemical background.

For each consumable:
-Produced in a way that is amenable for mass production (e.g. injection molding)
-Each device should have the same foot-print as the current commercial off the shelf unit.
-Each consumable should have a shelf-life of one year and ideally require no cold chain. The ability to store at room temperature will be seen as a strength and is not necessarily a requirement.
-Each cartridge should also have a mechanism to protect the 'spray-tip.'

PHASE III DUAL USE APPLICATIONS: Should the prototypes successfully meet all criteria set forth during the phase II effort each consumable should be produced in sufficient quantities for distributed to at least three different laboratories for independent validation. These independent groups could span both academia, government, and another potential commercial partner with significant resources and customer base amendable to launching a successful a production and marketing campaign. Also during the Phase III effort, the performers may also make improvements to the design based upon the finding during the Phase II testing and evaluation. This product would fulfill needs across a wide customer base including medical facilities, first responders, and private practices to aid in diagnosis. It would be extremely beneficial across all branches of the military for both threat detection and diagnosis.

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KEYWORDS: Paper Spray, Ambient Ionization, Direct Analysis, Mass Spectrometry, CWA, BWA, Threat Detection, PS-MS

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| A18B-T021 | TITLE: Large Scale Nano-Crystalline Coatings For Penetration Resistance |

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: Develop a fully dense nano-crystalline metallic coating with a high propensity for ballistic resistance using additive manufacturing.

DESCRIPTION: Current additive manufacturing (AM) and cladding processes have been shown to produce coatings and parts with interesting properties [1]–[4]. However, these processes have low deposition rates and are not readily scalable for large-scale production. Most AM processes also require inert atmospheres that limit the application of the technology to small parts and complicated environmental chambers and therefore limit the products capable of being fabricated/repaired [5]. Current additive manufacturing and coating processes deposit material at rates of 0.05 - 5 cm3/hr. significantly limiting the application and scalability of the process. New techniques such as the MELD process can deposit material up to 1000 cm3/hr. greatly increasing the size and number of parts that could potentially be coated.

The goal of this topic is to develop a ballistic resistant coating for metal panels. The coating process needs to have a deposition rate of at least 80 cm3/hr. in order to be economically viable on a large scale. The coating is expected to significantly increase the ballistic resistance performance of the panel with a minimum addition to weight and not display any adverse corrosion effects to steel. The proposed coating/process also needs to have the ability to repair/update current structures to address increased threats.

PHASE I: Demonstrate the feasibility of material coating prototypes that exhibit favorable properties for ballistic resistance. Develop a few small-scale 1ft x 1ft prototypes with nano-crystalline microstructures that were made with a deposition rate of at least 70 cm3/hr. Demonstrate the feasibility of applying the coating as a repair/update process to existing panels. The repair panels will be aluminum and steel but the process would be more favorable if applicable to other materials. Deliver a report documenting the research and development efforts along with a detailed description of the proposed methodology. The most effective process capable of producing the desired material properties will be determined and proposed for Phase II.

PHASE II: Manufacture the proposed coating technology. Develop a set of small-scale mechanical tests to demonstrate the performance of the developed coating. Apply the proposed coating methodology to a damaged panel as a repair method and demonstrate the repaired area has comparable properties to that of the original panel. Demonstrate that the technology could be used on a wide range of panel geometries and open environments. Determine the effects of varying specific structure/composition parameters on the mechanical performance of the prototype coating. Develop a parametric study that systematically varies the composition, microstructure, and processing of the material to determine the conditions for manufacturing operations. In addition, determine the environmental stability of the backing material: relevant variables to consider are temperature, corrosion resistance, and effects of strain rate.

PHASE III DUAL USE APPLICATIONS: The development of a coating that demonstrates a high ballistic resistant performance that can be applied as a repair/update to existing structures could increase performance of dated armor to match growing threats. The properties associated with a ballistic resistant material such as high wear resistance and toughness could also be beneficial to a large range of parts and the ability to apply in an open atmosphere and to varying geometries opens an endless amount of possibilities for applications.

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KEYWORDS: ballistic resistance, protection, coating prototypes, structures, toughness

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| A18B-T022 | TITLE: Developing Long-Term Malarial Chemoprophylactic Drug Releasing Implant |

TECHNOLOGY AREA(S): Biomedical

OBJECTIVE: The objective is to develop novel implantable malaria chemoprophylaxis formulations and conduct preclinical in vivo studies. Implantable long-acting malaria chemoprophylaxis serves the research aim of achieving increased force health protection of deployed service members in malaria endemic regions by by-passing daily oral dosing non-compliance and lowering deployed class 8 supply requirements.

DESCRIPTION: Successful prevention of malaria is highly dependent on compliance with a prescribed daily chemoprophylaxis regimen. However, maintaining drug compliance by U.S. service members can be difficult due to a daily oral dosing requirement, side effects such as nausea and photosensitivity, organizational culture, command emphasis and the demands of the operational environment. An example of the failure to prevent malaria infection occurred in Liberia in 2003, in which approximately 36% of deployed Marine Corps personnel (80 out of 220) were infected with falciparum malaria due to inadequate use of personal protective measures and poor adherence to the prescribed chemoprophylaxis [1]. Forty-six of those individuals required evacuation, and 5 of 80 marines (6.25%) presented with severe malaria requiring ICU admission. The development of an implantable long-acting chemoprophylaxis device with sufficient potency, safety equal to the current standard of care, and less cumbersome in dosing regimen and class 8 space requirements would serve as a significant improvement in preventative care for deployed service members in austere malaria endemic regions.

Several FDA-approved drug delivery systems perform as implantable polymer matrices. These drug-impregnated devices are currently for birth control and to lessen the effects of opioid addiction [2, 3]. In the case of the opioid addiction product, rods are implanted subdermally, e.g., in the inner upper arm, in a simple office-based procedure under local anesthesia, and removed in a similar manner at the end of the treatment period. The drug is delivered from the implant through the process of dissolution-controlled diffusion resulting in passive tissue absorption of the target drug and a stable blood level over time. Preclinical and clinical testing demonstrates this drug delivery platform can provide targeted, steady state (“round-the-clock”) blood levels of drug for a period of three to twelve months.

PHASE I: Required Phase I deliverables will include producing malaria chemoprophylactic compound-containing matrix, conducting in vitro characterization, and down-selecting anti-malarial compound candidates. Candidates should include FDA-approved anti-malarial prophylactic drugs, doxycycline and Malarone® (atovaquone/proguanil). In vitro testing should demonstrate rate of dissolution within existing safety and efficacy parameters, periodicity of dissolution consistent with a target product profile of 3 to 12 months of activity in an adult human, and include toxicity assessments that inform later in vivo experiments.

PHASE II: Phase II will implement a series of in vivo rodent and non-human primate (NHP) experiments with the suitable formulations from Phase I to evaluate toxicity, pharmacokinetics (PK) and efficacy performance parameters as malaria chemoprophylaxis. Efficacy and PK of implants should be evaluated with a well-established rodent model of malaria using parasite challenge with Plasmodium berghei and preferably using an in vivo imaging system so that direct comparisons between the current standards of care can be assessed [4]. Once later stage pre-clinical formulations are validated in murine models, higher-fidelity NHP in vivo testing should be used to assess the possible duration of implant prophylactic efficacy, and efforts should be made to tailor potential implant/drug formulations to meet the needs of military personnel who are frequently deployed for durations of 3 to 12 months. A successful Phase II development effort will culminate in an implantable device + FDA-approved compound combination that demonstrates viable malaria prophylaxis, and will outline success criteria for follow-on clinical studies in human prophylaxis phase I through III trials.

PHASE III DUAL USE APPLICATIONS: The vision or end state for this product is FDA approval for an implantable device that prevents malaria for 3 to 12 months, increases patient compliance, lowers undesirable side effects, and can be administered and removed without or with local anesthetic at the military role 2 level of care or its equivalent. The suggested regulatory pathway for FDA approval of an implantable device is the 505 (b) (2) drug/device mechanisms, with the objective of linking the approval process for the implant device to the reference-listed drug (RLD), which in this case would be the FDA-approved products Doxycycline or Malarone®. A possible funding source for early clinical trials is the Joint Warfighter Medical Research Program (JWMRP) through the Joint Program Committee-2 (JPC-2) under the Congressionally Directed Medical Research Program (CDMRP), which offers focused support for early clinical testing of medical solutions. A viable commercial technology transfer partner would be required to complete the full FDA-approval process. Potential commercial applications for a device that meets the military malaria prophylaxis target product profile would be for travelers, aid/development/industrial workers and partner militaries operating in malaria-endemic regions.

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KEYWORDS: malaria, antimalarial, chemoprophylaxis, implantable

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| A18B-T023 | TITLE: Development of Radar Absorbent Textile Cloth for Soldier Uniforms |

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: To design, fabricate and demonstrate materials that can be effectively worn by the Soldier that reduce their signature and mitigate the detection of their movement from ground surveillance radar (GSR) threats in the battlefield.

DESCRIPTION: Radar absorbing and shielding technology has attracted a growing interest due to the recent advances in enemy electronic warfare and detection capabilities, leaving US forces, especially infantry forces, vulnerable to detection across the electromagnetic spectrum. Advanced Battlefield and Ground surveillance radar (BSR/GSR) are readily available in military markets that are highly effective, portable, and automated for large area monitoring. To counter these threats, studies of radar absorbing materials with proper thickness, cost, efficiency, weight, hardness/flexibility, stability and electromagnetic and physical compatibility are ongoing for protection in differing applications such as: navigation, aircraft technology, radio and electronic devices, and wireless systems (1). In military applications, electro-optics and electromagnetic features on textile substrates and fibrous materials play an important role in the ability to camouflage by muting Soldier movements on the battlefield (2). Stealth movement of infantry on the battlefield is a key priority for the military. This proposed call will focus specifically on Soldier signature management by altering/functionalizing clothing with radar absorbing materials to address ground surveillance radar threats by reducing Soldier signature. While there exists a wide variety of radar absorbing material (RAM) composites for shelters and vehicles (3), there are currently no effective and lightweight wearable options to mitigate GSR detection of a dismounted Soldier.

PHASE I: This phase of the program must show the feasibility of the technical approach through a demonstration of the preliminary designs ability to reduce the radar cross section of a characterized baseline material. The baseline material must be representative of current operational clothing and individual equipment systems (e.g. Soldier uniform, body armor, helmet, rucksack, etc.) The material must demonstrate successful performance in the X and Ku frequency bands. The feasibility assessment must include the scientific and technical rational for how the preliminary material will scale and perform effectively. 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. Sample material must be delivered at the end of Phase I as well as a complete characterization of its mechanical properties, spectral absorbent effectiveness and design.

PHASE II: This phase will scale the successful Phase I technology into prototypes for lab and field based evaluations. Prototypes must demonstrate lab and field based capabilities within the X and Ku frequency bands at distances up to 12 km. Prototypes will range from a standardized 1 m2 test sample to representative operational clothing and/or operational equipment (e.g. body armor carrier, rucksack, etc.). The performance of the test samples and prototypes must be evaluated in laboratory and field settings and assessed in terms of radar cross section reduction, flexibility, durability, breathability and air permeability. The prototype materials must be tested and clearly demonstrate consistent functional properties under simulated operational use to include environmental factors such as a wide range of temperatures (-30 – 125ºF) and environmental factors (e.g. high humidity, rain, etc.) The final deliverable must also include a commercialization assessment and the viability of mass producing the developed technology.

PHASE III DUAL USE APPLICATIONS: This final phase will demonstrate the scalability, reliability, repeatability and operational application of the proposed technology. The technology developed under this effort has direct application to Soldier operational clothing and individual equipment. The results of this effort may culminate in the development a new material that could either replace standard materials used in uniforms, body armor carriers and rucksacks or integrate into the standard materials and substrates used in fielded systems.

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KEYWORDS: Radar absorbing materials, functional textiles

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| A18B-T024 | TITLE: Novel Method for Functionalizing Fibers and Textiles |

TECHNOLOGY AREA(S): Chemical/Biological Defense

OBJECTIVE: The objective of this topic is to develop a novel method of functionalizing fibers and textiles with particles and/or molecules that does not adversely affect the functionality of the particle or molecule, is durable, does not adversely affect the properties of the fiber or textile, and can be scaled in a way that is not cost prohibitive. In addition, the novel method must be able to be used with varying kinds of molecules and/or particles on different kinds of fibers/textiles.

DESCRIPTION: Currently, attempts to incorporate functionalities such as chemical reactivity, anti-microbial properties, vector protection, selective sorption or low-cost fire resistance into protective fabrics and garments are limited by the capability of existing textile manufacturing processes. Many novel molecules and particles of interest are not able to be used in the pad/roll dip coating processes due to the chemical constraints of textile processing plants or require extremely long residence times for curing or particle attachment and growth such that the process is not cost effective. Embedding particles in polymer fibers occlude active sites and reduce the functionality of the particles being embedded. Similarly, binding agents and other adhesives also reduce the active sites of the particle. Other processes such as atmospheric plasma deposition and microwave attachment are dependent on the structure and properties of the molecule or particle being attached and often change or destroy the original structure [1]. Chemical surface modification requires treatment of textiles with liquid reagents that penetrate into the textile fabric in order to create reactive functional groups which is not repeatable between different polymers with different molecular weight and crystallinity levels [2].

The requirements for this topic are, to the best of the proposer’s ability, to develop a scalable novel method of incorporating molecules and/or particles into fibers or textile substrates which are not dependent on the properties of the substrate or the molecule/particle to be attached and doesn’t adversely affect the functionality of the desired molecule or particle. In this way, the process for functionalizing fibers and textiles will be flexible and adaptable to the many substrates and functionalities required by the military in different applications.

PHASE I: Demonstrate two or more functionalizations of fiber and/or textile substrates on a lab scale on one natural and one synthetic fiber substrate such as: cotton knit, 50/50 Nylon/Cotton woven blend, polyurethane or polypropylene nanofibers or microfibers, or an inherently flame resistant fabric. Demonstrate that the functionality of the textile or nonwoven fiber substrate is durable after laundering. Swatches should be laundered per AATCC 135 “Dimensional Changes of Fabrics after Home Laundering” and tested before and after laundering for the durability of the functionality. For example, if vapor sorption is the functionality, the sorption capacity should be measured both before and after laundering. If chemical reactivity is the functionality, the reactivity in solid state before/after laundering. If flame resistance is the functionality, ASTM F1358, should be used to evaluate the FR properties before/after laundering. If anti-microbial properties are the functionality, then ASTM 147 and ASTM 100 on gram-negative Pseudomonas aeruginosa and gram-positive Staphylococcus aureus should be used before/after laundering [3]. A cost estimate for the manufacturing process is requested at the end of Phase I.

PHASE II: Demonstrate that 3 – 4 textiles and non-wovens of different fiber compositions can be functionalized with 3 - 4 molecules or particles with different properties (consult with TPOC as to which textiles and functionalizations are appropriate). The same tests should be completed at this stage as Phase I in order to ensure that the new functionality is durable in the face of laundering. Physical properties of the textile substrates should also be tested before and after functionalization in order to show the effect on air permeation [4], moisture vapor transmission rate [4], stiffness (ASTM D747) and tensile strength (ASTM 638) to ensure that the textiles can be used in a variety of applications. The method of incorporation of the functionality should transition from a batch to continuous process with similar results in terms of functionality, textile properties and durability. Several yards of full scale (~60”) of 3 – 4 functionalized textiles should be delivered.

PHASE III DUAL USE APPLICATIONS: This phase will focus on the commercialization of the novel functionalized textiles. The TOPCs will be available to advise on possible partners and path forward in both government and industry; however the over goal would be to deliver prototypes with novel functionalized textiles for the intended end-user. For example, sorptive and/or reactive garments would be needed by within the Chemical/Biological community in the military and first responder community. Flame resistant garments are needed by the first responder community and US military. Vector protection is needed by survivalists, campers, as well as the military. Friend/Foe identification is needed by the military. Reactive textiles for sensors are needed by both the military and sportswear companies, and anti-microbial textiles are needed for the military, hospitals, sportswear companies and the first responder community. System level evaluations of the prototypes should be performed.

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KEYWORDS: Protective Textiles, Chemical/Biological Protective Materials, Flame Resistant Textiles, Functionalized Fibers and Textiles

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| A18B-T025 | TITLE: Squad Multipurpose Equipment Transporter (SMET) Tele-Operation Feedback System |

TECHNOLOGY AREA(S): Ground/Sea Vehicles

OBJECTIVE: To develop a modular tele-operation feedback system which can be integrated easily for any SMET system and the Operator Control Unit (OCU) for safety and operational effectiveness.

DESCRIPTION: Since 2012, the US Army has been evaluating numerous versions of Squad Multipurpose Equipment Transport (SMET) vehicles. In one exercise, spanning two months, an infantry company and combat engineer squad tested nearly a dozen dissimilar SMET surrogate vehicles designed and provided by multiple vendors. Of note it was discovered that;

“ALL of the surrogate systems experienced problems with rollovers. The narrower SMET vehicles had more trouble with side slopes, but even the wide-width systems overturned. Dynamic stability is a notoriously difficult problem for remotely operated systems. Taking the operator out of the vehicle eliminates any vestibular and proprioceptive sense of the vehicle stability. Consequently, this situation is compounded when operating the vehicles, at night, in rough terrain, using night vision goggles.” [1]

 Additionally, it was found that while a wider chassis platform having a lower Center of Gravity (C.G.) may help to mitigate rollover, it may also impede mobility of the SMET in tight spaces. Tele-operation resulted in the same probability of vehicle rollover without the help of a tele-operator assist system.

 We are proposing the investigation and development of a tele-operation feedback system that will act as operator assist for the SMET type vehicles. Fundamentally, this system in the SMET, with cargos, should calculate the location of the vehicle’s C.G. at standard intervals (every 10 milliseconds, for example) and transmit this information to the OCU. Any developed system should also be enabled to compute current C.G. locations in a moving vehicle for dynamic comparison with a known rollover threshold to provide warning to the OCU. The OCU may be fitted to display warnings to the Operator (such as amber lights or vibration of the unit) as the C.G. location approaches the rollover threshold, and the OCU may also indicate that the vehicle is in a non-rollover position as the Operator changes the direction of the SMET. This research should also investigate the application of a self-learning system and training of deep neural nets as a part of the tele-operation feedback system to reduce Soldier’s workload during the mission.

PHASE I: Simple Model for Proof of Concept. A software model and limited physical testing will be performed in a proof of concept study. A software model will be developed that successfully calculates the C.G. location of a robotic wheeled vehicle supporting multiple cargo loads as they are loaded at various location on the robotic vehicle. Modeling and simulation will be used to prove the mathematical model. The software will be loaded into an Electronic Control Unit (ECU) and an interface will be developed and configured to, at least, one design of robotic vehicle and Operator Control Unit (OCU) at TARDEC for testing.

PHASE II: Configuration Dependent Model. Sensors will be integrated with each strut of the robotic vehicles for both wheeled and tracked vehicles. These sensors will be used to compute more detailed movements and positions of each strut and determine more accurate C.G. locations in a moving robotic vehicle on various terrains. This Phase II research will also introduce and develop a self-learning system and training of deep neural nets.
 Simulation and modeling will be required for the mathematical design of the self-learning system to ensure accuracy and proof that it is applicable to various configurations of wheeled and tracked robotic vehicles. The software will be loaded on an Electronic Control Unit (ECU) and an interface will be developed that is configured to various configurations of robotic vehicles and OCUs at TARDEC for testing.

PHASE III DUAL USE APPLICATIONS: Dual use Configurations. Vision: The tele-operation feedback system is envisioned to become the basis of future tele-operation/semi-autonomous/autonomous vehicles, as a modular plug-in system for the military, because SMET variants are anticipated to feature strongly in future Soldier missions. Additionally, as commercial shipping/delivery companies expand their delivery methods to utilize ground-based autonomous/semi-autonomous and tele-operated systems, many ground based delivery vehicles will benefit from this system for safety and delivery completion. Future modifications may lead to a “predictable” feedback system, which could greatly enhance the tele-operation system’s usability and effectiveness.

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KEYWORDS: Semi-Autonomous, Autonomous, Sensor, Dynamic Feedback System, Modular, Attitude Indicator, Rollover

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