ARMY STTR 15.A
PROPOSAL SUBMISSION INSTRUCTIONS

Revised Closing Date: February 25, 2015, at 6:00 a.m. ET

Listed below are the approved FY15.A topics solicited for in the Army's Small Business Technology Transfer (STTR) Program. Offerors responding to the Army STTR FY15.A Solicitation must follow all general instructions provided in the Department of Defense (DoD) Program Solicitation. Specific Army requirements that add to or deviate from the DoD Program Solicitation instructions are provided below with references to the appropriate section of the DoD Solicitation.

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 harnesses the collective knowledge and experience of scientists and engineers, across nine Army organizations, to identify and put forward research or research and development (R/R&D) topics that are consistent with the mission of their organization and the purpose of the STTR program – i.e., to stimulate a partnership of ideas and technologies between innovative small business concerns (SBCs) and research institutions (RIs) through Federally-funded R/R&D to address Army needs. Information about the Army STTR Program can be found at https://www.armysbir.army.mil/sttr/Default.aspx.

For technical questions about specific topics during the Pre-Solicitation period (12 Dec 2014 – 14 Jan 2015), contact the Topic Authors listed as POCs for each topic in the Solicitation. To obtain answers to technical questions during the formal Solicitation period, visit http://www.dodsbir.net/sitis. For general inquiries or problems with the electronic submission process, contact the DoD SBIR/STTR Help Desk at [1-800-348-0787] or Help Desk email at [sbirhelp@bytecubed.com] (8:00 am to 5:00 pm ET). Specific questions pertaining to the Army STTR Program should be submitted to:

Dr. Bradley E. Guay
Army STTR Program Manager
usarmy.rtp.aro.mail.sttr-pmo@mail.mil

US Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709
(919) 549-4200
FAX: (919) 549-4310

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 have insufficient merit. Phase I contracts are limited to a maximum of $150,000 over a period not to exceed six months. Army STTR employs only government employees in a two-tiered review process. Awards will be made on the basis of technical evaluations using the criteria described in this DoD solicitation (see section 6.0) and availability of Army STTR funds.

The DoD SBIR/STTR Proposal Submission system (http://www.dodsbir.net/submission/) provides instruction and a tutorial for preparation and submission of your proposal. Refer to section 5.0 at the front of this solicitation 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 Solicitation).

Proposals addressing the topics will be accepted for consideration if received no later **6:00 a.m. ET, Wednesday, 25 February 2015**. The Army requires your entire proposal to be submitted electronically through the DoD-wide SBIR/STTR Proposal Submission Web site (http://www.dodsbir.net/). A hardcopy is NOT required and will not be accepted. Hand or electronic signature on the proposal is also NOT required. 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. Proposals are required to be submitted in Portable Document Format (PDF), and it is the responsibility of submitters to ensure any PDF conversion is accurate and does not cause the Technical Volume portion of the proposal to exceed 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] or Help Desk email at [sbirhelp@bytecubed.com] (8:00 am to 5:00 pm ET).

Companies should plan carefully for research involving animal or human subjects, biological agents, etc (see sections 4.7 - 4.9). The few months available for 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 in the DoD Solicitation 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

Commencing with the Phase IIs resulting from the STTR FY13.A cycle, all Phase I awardees may apply for a Phase II award for their topic – i.e., no invitation required. Any proposers with Phase I awards from years *prior* to FY13.A, however, must receive an invitation from their awarding office in order to apply for a Phase II. 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). 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/. The submission period in FY16 will be 30 calendar days starting on or about 15 February 2016. 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. Proposals received by the Department of Defense at any time other than the prescribed submission period will not be evaluated.

Phase II proposals will be reviewed for overall merit based upon the criteria in section 8.0 of this solicitation. STTR Phase II proposals have four Volumes: Proposal Cover Sheet, Technical Volume, Cost Volume and Company Commercialization Report. 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 toward the 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 Solicitation, 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 Phase II period not to exceed the maximum dollar amount of $1,000,000 (or $750,00 for Phase II submissions from Phase I contracts awarded prior to FY13). During contract negotiation, the contracting officer may require a Cost Volume for a base year and an option year. These costs must be submitted using the Cost Volume format (accessible electronically on the DoD submission site), and may be presented side-by-side on a single Cost Volume Sheet. The total proposed amount should be indicated on the Proposal Cover Sheet as the Proposed Cost. Phase II projects will be evaluated after the base year prior to extending funding for the option year. Phase II proposals should be 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 > $500,000 if program funds are unavailable.

DISCRETIONARY TECHNICAL SSISTANCE (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. The Army has stationed eight 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, starting in FY14. Details related to DTA are described in section 4.22 of the DoD Solicitation. For more information go to: **https://www.armysbir.army.mil/sbir/TechnicalAssistance.aspx**

PUBLIC RELEASE OF AWARD INFORMATION

If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released via the Internet. Therefore, do not include proprietary or classified information in these sections. For examples of past publicly released DoD SBIR/STTR Phase I and II awards, visit http://www.dodsbir.net/awards.

NOTIFICATION SCHEDULE OF PROPOSAL STATUS AND DEBRIEFS

Once the selection process is complete, the Army STTR Program Manager will send an email to the individual listed as the "Corporate Official" on the Proposal Coversheet with an attached letter of selection or non-selection. The notification letter referenced above will provide instructions for requesting a proposal debriefing. Small Businesses will receive a notification for each proposal that they submitted. The Army STTR Program Manager will provide ***written*** debriefings upon request to offerors in accordance with Federal Acquisition Regulation (FAR) Subpart 15.5. Please read each notification carefully and note the proposal number and topic number referenced. All communication from the Army STTR PMO will originate from the program specialist's e-mail address.

DEPARTMENT OF THE ARMY PROPOSAL CHECKLIST

This is a Checklist of Army Requirements for your proposal. Please review the checklist to ensure that your proposal meets the Army STTR requirements. You must also meet the general DoD requirements specified in the solicitation. **Failure to meet all the requirements will result in your proposal not being evaluated or considered for award**. Do not include this checklist with your proposal.

1. The proposal addresses a Phase I effort (up to **$150,000** for up to six-month duration).
2. The proposal is limited to only **ONE** Army Solicitation topic.
3. The technical content of the proposal includes the items identified in section 5.4 of the Solicitation.
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://cmra.army.mil/).
7. If applicable, the Bio Hazard Material level has been identified in the Technical Volume.
8. If applicable, 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. An employee must have an H-1B Visa to work on a DoD STTR contract.

Army STTR 15.A Topic Index

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Army STTR 15.A Topic Descriptions

A15A-T001 TITLE: Advanced Printed Circuit Board Design Methods for Compact Optical Transceiver

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Apply advanced and novel printed circuit board and electronic design methods to reduce or eliminate cross coupling and electromagnetic interference on miniature printed circuit boards which contain high peak power pulsed laser diodes and wideband, high gain optical receiver electronics.

DESCRIPTION: The desire for compact, low cost laser ranging and proximity sensors continues to push the limits of standard electronic design methods and printed circuit board (PCB) manufacturing techniques. Advances and maturation of high peak power, pulsed junction laser diode and vertical cavity surface emitting lasers (VCSELs) have brought the cost and availability of these devices to the point of practical use in compact low cost sensors. The requirement for low cost and size pushes the sensor designer to place the sensitive, high speed receiver electronics onto the same PCB and in close proximity to the noisy transmitter electronics. Typical pulsed laser diode peak currents are in the tens of amps while the receiver electronics is required to detect narrow (<10 nanoseconds) pulses in the tens of nanoamps range. This requires that the cross coupling and electromagnetic interference (EMI) between the transmitter and receiver must be reduced by 10 orders of magnitude or more. The purpose of this STTR is to develop and apply novel printed circuit board design and layout techniques and/or electronic design methods as required to achieve this kind of isolation. This will allow the laser diode transmitter circuit and high speed detector/receiver electronics to coexist on the same printed circuit board and to reduce the size of this printed circuit board making its use practical for more applications.

PHASE I: The contractor and research institute shall develop and demonstrate a design methodology that is capable of producing a compact optical transceiver PCB (Area<6cm^2) containing either a junction laser diode or VCSEL having a pulsewidth in the 3-8 nanoseconds range and a peak power of >20 watts along with a detector and amplifier capable of detecting these pulses when the total peak power incident on the detector is 550 nanoWatts or greater and can be received 3 to 300 nanoseconds after the laser pulse is transmitted. The detector must have an active area of at least 1mm square. This capability can be demonstrated by either modeling or prototype PCB hardware measurements.

PHASE II: The contractor and research institute shall demonstrate the principles derived from Phase I by building printed circuit boards that are capable of meeting the requirements set forth in Phase I. This will be accomplished on separate PCB's using both junction laser diodes as well as VCSELs.

PHASE III DUAL USE APPLICATIONS: Miniaturized optical transceiver printed circuit boards could provide more compact alternatives for laser ranging and proximity sensors both in military and commercial applications.

REFERENCES:
1. MT-095 Tutorial, "EMI, RFI, and Shielding Concepts", 2009, Retrieved from http://www.analog.com/static/imported-files/tutorials/MT-095.pdf.

2. Analog Dialogue Volume 39 - September 2005, "A Practical Guide to High-Speed Printed Circuit Board Layout", by John Ardizzoni, Retrieved at http://www.analog.com/library/analogDialogue/archives/39-09/layout.html.

3. Semiconductor Today, 8 July 2014, "VCSEL quasi-array of four device outputs 210W at 110A", Retrieved from http://www.semiconductor-today.com/news_items/2014/JUL/CIO_080714.shtml.

KEYWORDS: printed circuit board manufacturing techniques, compact optical transceiver, laser ranging, proximity sensor, printed circuit board design, cross-coupling, electromagnetic interference, EMI, VCSEL

A15A-T002 TITLE: Advanced Computational Technologies for Multiphase Internal/External Coupled Ballistic Flows

TECHNOLOGY AREAS: Weapons

OBJECTIVE: To build a high fidelity framework for the treatment of multiphase, multiphysics internal and accompanying external ballistic flows, and to develop algorithms and computer software that will implement these in military and commercial simulation applications.

DESCRIPTION: Ballistic systems operate in flow regimes characterized by high speeds, high temperature, high pressure, with reacting turbulent multiphase multi-species fluids, with various forms of fluid-structure interactions. Thus, these flow conditions represent a challenging area for high fidelity numerical simulation. Advanced computational technologies are required that achieve both high fidelity and efficiency on modern parallel/distributed architectures in order to advance our understanding of the conditions occurring during internal weapon operations and the resulting external flows. Specific areas of interest include fluid-structure interaction between the moving projectile, the barrel, propellant gases, and particulate flows including burning of propellant which drives the operation of the weapon system, the particulate based aspects of erosion and fouling along internal flow paths of weapons systems (and accounting for particulates which can deform or change shape or size, such as when propellant grains burn and particulates melt and solidify as they interact with flow surfaces), the muzzle flow conditions and potential contributions to chemical reactions as gases exit into the surroundings, and also in the transport and ejection of multiple projectiles into the surroundings.

Development and implementation of advanced numerical methods can improve the modeling effectiveness and efficiency of the above phenomena occurring particularly during small arms system operation. Simulation capabilities must allow for large scale motion and interactions of solid bodies within a fluid at high temperatures, pressures, and velocities. Efficient and accurate methods of parallelized mesh generation, mesh adaption, and re-meshing are needed to track and capture the motion of the particles through the turbulent flow as well as to establish flow conditions, including shock wave propagation. Methods to simulate the interactions/collisions between multiple solid bodies are needed, in addition to accurate resolution of the flow and fluid-induced forces around each object in the turbulent flow. These methods must handle rigid body motion as well as potential particle deformation or shape changes that may result. In the conditions of interest, particulate interactions and fluid-particle interactions must be accounted for. Discrete particle motion tracking is necessary with the proper particle-particle, particle-flow surface interactions/collision modeling techniques for the material conditions/flow conditions at hand. Physical models must be implemented within the computational framework for the exchange of mass, momentum, and energy as particles move, deform, change size and/or shape, combust, melt, or solidify.

PHASE I:
a. Survey of existing techniques and selection of candidate methods for extension for high-fidelity multiphysics modeling and adaptive mesh control in the various demanding scenarios involved in internal-flow ballistics modeling and the resulting external flows. This includes implementing recent advances in mesh generation and regeneration [1], stabilized and multiscale finite element formulations, multiphase flows [2], front tracking [3], and uncertainty quantification.
b. Development of a general computational infrastructure for implementing these candidate methods in applications involving:
i. Two phase solid-gas flows involving high speed, pressure, and temperature, for discrete particle tracking to follow particle motion, for dense particle concentrations where particle-particle interactions are important, and where particles change the flow [4].
ii. Fluid-structure interaction that models the fluid-driven motion of solid bodies (both rigid and deforming) where motion is large compared to the mesh size, and that models gas flows at high speed, pressures, and temperatures [5,6].
iii. Liquid particles, such as multiphase flows involving solid-gas-liquid. Methods will be appropriate for conditions typical in small arms systems, able to simulate laminar through turbulent flows and able to handle the high pressure (up to 370MPa), velocity (1000m/s), and temperature (up to 3500K) extremes found in gun systems as well as the low pressure/temperatures that can occur during gas expansion. Particulate concentrations well over 20% should be considered.

c. Conduct proof-of-concept 3D computations to demonstrate the accuracy of the candidate methods, and make arguments (or estimates or demonstrations) for the speedup/scalability of this framework on modern parallel/distributed architectures.

PHASE II: The techniques of Phase I shall be implemented in software, accuracy and scalability will be demonstrated in high performance computing environments, and the software will be marketed both within government laboratories (in particular to the US Army Armament Research and Development Engineering Command at Picatinny Arsenal [ARDEC]) and within the related civilian industries of small caliber weapons design and internal combustion engineering. In particular:

a. The technique designed during Phase I will be implemented in software. The salient features of the following scenarios will be demonstrated:

i. Modeling particulate flow internal to a weapon - propellant, soot, copper (fouling and erosion), propellant burn, multi-body and multi-projectile systems [4,5,6].

ii. Modeling bullet motion along barrel, weapon mechanism motion, projectile/barrel/rotating band interaction, motion of valve and gaskets in unconventional gun design [6].

iii. Performing general analysis of droplet/gas flow/surface interaction, and molten copper moving along surfaces of internal flow paths and solidifying.

b. To ensure compatibility with unstructured mesh solvers the mesh adaptation procedures should be capable of operating in parallel on distributed meshes that can be dynamically rebalanced as the mesh is evolved. All procedures need to operate on distributed meshes for effective parallel computation [2].

c. Users will be provided the ability to tailor the software for scenarios outside the capabilities of the delivered version without having to go deep into its structure or introducing any major changes, for example through access to the code and through user-modified subroutines. This capability will be demonstrated experimentally.

d. A complete series of 3D numerical tests will be run, showing the performance of the proposed methodology in a production computational environment. A set of test cases will be provided for testing of both accuracy and efficiency, in conditions typical of ballistic systems applications.

e. The portability of the designed software to a variety of available architectures/platforms will be investigated and optimized. Special attention will be given to implementation on parallel high performance computing (HPC) clusters.

f. The final portable version of the software will be made available to interested government parties for assessment and use, in particular to the US Army ARDEC.

g. Interested users in academia and private industry will receive access to the software under appropriate licensing agreements.

h. A comprehensive set of software documentation will be prepared and made available to users. This will include both documentation on use and on how to tailor the software for scenarios outside the capabilities of the delivered version.

i. Theoretical and numerical results of the study will be published in the peer-reviewed literature.

j. A long-term program for maintenance and subsequent improvement of the software will be created.

PHASE III DUAL USE APPLICATIONS: The technology developed will substantially improve the performance of existing internal combusting flow codes, such as are used in both defense and commercial ballistic delivery systems. It will apply recent advances in computational mathematics to the extreme speed, temperature, pressure, reacting, turbulent, multiphase, multi-species flow regimes of internal flows and coupled external flows for higher fidelity modeling capabilities within the ballistic delivery industry. It will apply advanced computational technologies to achieve higher run-time efficiencies on modern parallel/distributed architectures. This will lead to significant speed-ups in the design time of military ballistic weapons, and will be equally useful for the design of similar systems in commercial applications.

REFERENCES:

1. Remacle, J. F., Li, X., Shephard, M. S., & Flaherty, J. E. (2005). Anisotropic adaptive simulation of transient flows using discontinuous Galerkin methods. International Journal for Numerical Methods in Engineering, 62(7), 899-923.

2. Galimov, A. Y., Sahni, O., Lahey Jr, R. T., Shephard, M. S., Drew, D. A., & Jansen, K. E. (2010). Parallel adaptive simulation of a plunging liquid jet. Acta Mathematica Scientia, 30(2), 522-538.

3. Glimm, J., Grove, J. W., Li, X. L., Shyue, K. M., Zeng, Y., & Zhang, Q. (1998). Three-dimensional front tracking. SIAM Journal on Scientific Computing, 19(3), 703-727.

4. Florio, L. A. (2013). Direct particle motion and interaction modeling method applied to simulate propellant burn. Applied Mathematical Modelling, 37, 5606-5626.

5. Loncaric, S., Greatrix, D. R., & Fawaz, Z. (2004). Star-grain rocket motor–nonsteady internal ballistics. Aerospace Science and Technology, 8(1), 47-55.

6. Yu, W., & Zhang, X. (2010). Aerodynamic analysis of projectile in gun system firing process. Journal of Applied Mechanics, 77(5).

7. Kees, C. E., Farthing, M. W., Berger, R. C., & Lackey, T. C. (2009). A Review of Methods for Moving Boundary Problems (No. ERDC/CHL-TR-09-10). US Army Corps of Engineers Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS.

8. Florio, L.A. (2012). Modeling particulate flow phenomenon in small arms systems. Presented at AlaSim 2012, May 2012.

KEYWORDS: internal flow, multiphase flow, combusting flow, computational ballistics, manufacturing processes

A15A-T003 TITLE: Intracavity Nonlinear Optical Generation of THz Radiation

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The efficient generation of 1-4 THz coherent radiation with a particular emphasis on the ~1 THz range with nonlinear optical generation obtained by difference frequency generation.

DESCRIPTION: Current sub-THz sources utilize Schottky-diode based multipliers for the state-of-the-art performance [1]. On the high frequency side of the "THz gap", quantum cascade lasers have shown promise; however, only nonlinear optical approaches show promise for RT (room temperature), monolithic multi-mW continuous wave (CW) power levels in the 1-4 THz regime [2-5]. Nonlinear optical generation of 1-6 THz frequency radiation has been achieved through a number of approaches using various materials; however, the efficiency of the nonlinear conversion falls-off in what is known as the "THz gap" around 1 THz. Intracavity generation of THz radiation indicates the possibility of obtaining relatively high power at room temperatures from a monolithic package.

Applications of such high power sources to THz spectroscopy [6] and imaging [7] are of interest and hold unexplored potential. Studies of these application fields at high power levels has been limited by the availability of the high power sources. The development of the sources will aid further research of THz techniques and their applications by making them available to leading THz laboratories. Thus, the development of such sources for use and distribution to the leading spectroscopy labs will be part of the commercialization goals in phase II and III. The efficiency, compactness, and high power output are the main considerations with an eye toward manufacturability of a significant number of the sources for use in various THz spectroscopy and imaging laboratories. Although intracavity nonlinear optical generation of THz radiation is the primary approach sought to achieve this goal, alternative approaches will be considered if the monolithic integration of that technology has promise as a next generation technology.

PHASE I: Using a proposed monolithic design, show evidence of feasibility of all major elements. Develop theoretical estimates with some experimental demonstration of THz signal generation in the proposed materials. Theoretical estimates should indicate the feasibility of 10 mW, CW RT at 4 THz and approximate mW power levels at 1 THz (also CW RT).

PHASE II: Fabrication and testing of the full monolithic THz source. Optimization of the laser sources and frequency conversion designs should be studied, implemented and tested. The general goals are to demonstrate mWs of power across the 1-4 THz spectrum (CW, RT), and 50 mW of power by the end of the program across at least a portion of the 1-4 THz spectrum.

PHASE III DUAL USE APPLICATIONS: Terahertz sources have potential uses in both DoD and civilian applications. Monolithically integrated, efficient RT CW radiation in the 1-4 THz regime will be useful for studies of spectroscopic sensing of various chemicals. Imaging in this regime will also be of interest with investment in beam quality which can be further explored with additional Phase III funding. Transition of the high power sources to various laboratories will be sought (DoD, NIST, DoE, universities, etc.) to study potential applications. Dual use applications may include various types of imaging and sensing of unknown and hidden objects, chemicals, and various biomolecules, as well as remote sensing applications in meteorology and climatology.

REFERENCES:
1. See www.vadiodes.com, for Virginia Diodes, Inc.

2. M.A. Belkin, F. Capasso, A. Belyanin, D.L. Sivco, A.Y. Cho, D.C. Oakley, C.J. Vineis, and G.W. Turner Nature Photon. 1, 288 (2007).

3. M. A. Belkin, F. Capasso, F. Xie, A. Belyanin, M. Fischer, A. Wittmann, and J. Faist, Appl. Phys. Lett. 92, 201101 (2008).

4. K. Vijayraghavan, R.W. Adams, A. Vizbaras, M. Jang, C. Grasse, G. Boehm, M. C. Amann, and M.A. Belkin, Appl. Phys. Lett. 100, 251104 (2012).

5. K. Vijayraghavan, R.W. Adams, A. Vizbaras, M. Jang, C. Grasse, G. Boehm, M. C. Amann, and M.A. Belkin, Nature Comm. 4, 2021 (2013).

6. P. H. Siegel, "THz Technology," IEEE Trans. Microwave Theory and Techniques 50th Anniversary Issue, vol. 50, no. 3, pp. 910-928, March 2002.

7. K. B. Cooper, R. J. Dengler, N. Llombart, A. Talukder, A. V. Panangadan, C. S. Peay, I. Mehdi, P. H. Siegel, "Fast, high-resolution terahertz radar imaging at 25 meters," Proc. SPIE v. 7671, 2010.

KEYWORDS: intracavity, nonlinear optics, Terahertz

A15A-T004 TITLE: Stochastic Electromagnetic / Circuit Analysis

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a framework and software package for integration with commercially available full wave electromagnetic (EM) / circuit simulation software that will support the efficient, accurate analysis of the effects of system variability on the performance of electronic systems consisting of antennas, platforms, circuit boards, and integrated circuits composed of passive and active (linear and nonlinear) circuit elements.

DESCRIPTION: Recent advances in full wave electromagnetic (EM) simulations coupled with circuit analysis routines of integrated circuits consisting of active and passive elements have made possible calculations of EM fields incident on complex structures consisting of antenna systems emplaced on vehicular or other platforms, which may have active or passive circuits integrated directly in the antenna system, and connected to circuit boards containing integrated circuits (IC's) and/or discrete circuit elements, including non-linear elements. The incident EM fields not only activate currents on the antenna and vehicle structures, but also couple into the integrated circuits via metal wiring, mainly on the circuit boards. Commercial EM / circuit analysis software is becoming available which can deal with the complications of these systems, however even when implemented in highly parallel architectures the accurate analysis of coupled EM and non-linear circuit elements is extremely consuming of computer time and memory resources. Real world embodiments of these complex EM / circuit systems involve a very high degree of uncertainty. For most applications the orientation, polarization, and strength of impinging EM fields is highly variable. There is a high degree of variability in the dimensions and electrical characteristics of conducting elements, wiring layout, the composition of circuit boards, and passive and active circuit elements due to manufacturing variances and to aging of components. In particular, the aging of active circuit elements can result in as much as 50% changes in critical electrical characteristics. Another major source of uncertainty occurs in attempting to understand the effect of EM fields created by a reasonably well known system on nearby systems for which the detailed electrical components are not well known and must be considered stochastically. Calculating the effects of these uncertainties on system performance using Monte Carlo style analysis with multiple computations of standard EM / circuit solvers or the statistical analysis of repeated experimental variations would be extremely impractical. An efficient stochastic based analysis software package which can efficiently handle these uncertainties would have a major impact on the design of commercial and military electronic systems involving EM structures coupled to circuits, on vulnerability analyses of these systems, on EM compatibility compliance and investigations. The vulnerability of friendly as well as hostile systems is of special concern for military electronic warfare applications.

Recent research on treating EM and circuit analysis of stochastic systems using stochastic macromodeling approaches have demonstrated advances in the ability to efficiently analyze specific situations, such as the wiring layout of circuit boards, the placement of fiber weave within circuit board composition, the variation in permittivity of dielectric material surrounding transmission lines, and the variation in the surface roughness of conductors. Examples of these approaches are discussed in the references to this topic and in the further references contained in each.

PHASE I: Develop a framework for the efficient statistical analysis of EM / circuit systems consisting of multiple antennas, vehicle platform, and circuit boards with IC's of active electronic elements using stochastic macromodel approaches. The framework should support the analysis of the effects on system performance of full variation in the orientation of antennas and circuit elements with respect to incident EM fields, the possible variations in placement of at least 3 antennas on a metal platform roughly the size and shape of a Bradley fighting vehicle, variations in circuit board wiring layout of as much as 1/10 wavelength, and variations in active circuit element (eg. amplifiers, oscillators, mixers) of as much as 50% due to aging. Use as a notional target 3 commercial transceiver packages in the UHF band, or use textbook circuit examples. Develop algorithms to implement the framework for the stochastic analysis of the circuit performance variation due to variation in EM field impinging on the circuit board. Demonstrate the algorithms integrated with commercially available EM / circuit software. Validate the analysis using Monte Carlo simulation and/or measurement. Develop a software plan for implementing the more general framework with standard commercially available software. Develop a detailed market strategy and plan.

PHASE II: Develop the algorithms to support the modeling framework, including antenna variation, connector variation, circuit board wiring layout variation, and variation in passive and active circuit elements, for the notional case of 3 antennas, 3 VHF band transceivers, mounted on a single vehicle of rough size and shape of a Bradley fighting vehicle. Incorporate the algorithms in a single software package appropriate for integration with commercially available EM / circuit simulators. Validate the resulting analysis using Monte Carlo statistical simulation and with selected experiments. Expand the modeling framework to include variation in the composition of the circuit boards themselves. Analyze the potential for massive parallel implementation of the stochastic modeling framework.

PHASE III DUAL USE APPLICATIONS: Develop algorithms to support the expanded modeling framework. Incorporate the algorithms into stochastic analysis simulation software in a CAD package. Develop an appropriate GUI for the stochastic analysis package. Produce a finished software product with training and instruction manuals and example problems. Demonstrate, document, and publicize the analysis of sample problems to demonstrate the package capabilities. The software package will impact the design, testing, and EMC compliance analysis of both commercial and military radio and radar systems and the vulnerability analysis of friendly and hostile systems for electronic defense and attack, respectively. The software package would be available either as a separate package capable of integrating with general EM / circuit analysis software, or directly integrated into commercially available EM CAD software. By providing the capability for fast simulation and analysis of the statistical variation in the performance of complex electronic and electromagnetic systems, particularly those integrated on vehicle platforms, such a CAD package will significantly reduce design and prototyping costs, enable a better analysis of system electromagnetic vulnerability, project degradation in performance due to aging, and enable better, more reliable and resilient designs. Potential customers would be DoD laboratory and research and engineering centers, EMC compliance laboratories, industry design centers for commercial electronic systems, and prime contractors supporting the design of military systems of record.

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KEYWORDS: electromagnetic analysis, RF circuit analysis, stochastic analysis, electronic CAD

TPOC: James Harvey
Phone: (703) 696-2533
Email: james.f.harvey.civ@mail.mil

A15A-T005 TITLE: Terahertz Nano-Radio Platform with Integrated Antenna and Power source

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop a nano-radio platform at terahertz frequencies with integrated antenna and power source.

DESCRIPTION: Integrated radio circuits and systems are indispensable for wireless sensor networks, implantable medical sensors, autonomous micro robots, tracking and remote control of insects, chip-to-chip links, etc. In these applications, it is essential to reduce the radio dimension as much as possible. For example, in the battlefield assessment, the small radio footprint makes the wireless sensor network harder to detect. In a different application, very low-power, small and light weighted radio can be placed on insects to remotely control motion of insects by electrically stimulating their nervous system and to understand how insects perform navigation. Insect-based wireless network connected in an ad hoc topology where insects equipped with miniature wireless sensors act as sensor nodes is also potentially realizable.

Past projects in radio miniaturization have targeted total system size of one cubic millimeter (10^-9 cubic meter) [1, 2]. Since most of these systems are designed to operate at microwave frequencies, the sizes of radio systems and therefore their antennas are significantly smaller than the wavelengths of the electromagnetic waves. Because of the antenna constraint, the range of these miniature radio systems is limited to only a few millimeters.

With the scaling of the CMOS integrated electronic technology, the transistor size is reduced by half every two years. In digital area, this has been successfully translated to the miniaturization of computational devices and increasing transistor count per die. On analog side, the cutoff frequency of state-of-the-art CMOS processes is approximately 500 GHz and expected to approach 1 THz by 2018. As a result, chip-scale THz sources and phased-arrays with integrated antennas based on CMOS technology have been demonstrated at 500 GHz and higher [3,4] and will surely be pushed to even higher frequencies. Integrated CMOS radio systems are also being explored at similar frequencies.

Radio system implemented at terahertz frequencies (300 GHz-3 THz) can dramatically reduce circuit chip and antenna size. THz frequencies also offer the advantage of improved radiation directivity and therefore increase range of the radio. By utilizing current development of THz CMOS technology, this R&D effort will develop a chip-scale THz nano-radio platform with bi-directional transmit/receive capability. The total size of proposed solution should be less than 10^-11 cubic meter including antenna and power source. Its operating range should be greater than 1 meter, its data rate greater than 200 kilobits per second, and power consumption less than 15 microwatts. The proposed solution should also explore networking of these systems to improve data throughput and achieve collaborative sensing and computation.

PHASE I: Perform trade study between system size, architecture, operating frequency, antenna structure, range, modulation format, data rate, power consumption, etc. Develop system level model of transmitter and receiver based on optimized parameters selected from the trade study. The system modeling should include choice of suitable power source or energy harvest techniques. Develop initial circuit implement and antenna design of the radio system. Phase I study should determine the feasibility of developing a THz nano-radio with an overall size of 10^-11 cubic meters based on current nano-CMOS technology.

PHASE II: Design and fabricate a complete nano-radio system at a desired frequency determined from Phase I including transmitter/receiver, antenna structure, and power source. The nano-radio must satisfy the requirements described earlier in size (10^-11 cubic meters), range (1 meter), power (15 microwatts) and data rate (200 Kbits). Demonstrate communication between a nano-radio node and an external node. The nano-radio node should be a standalone system without external wiring and the demonstration should clearly verify correct information is transmitted and received by the radio nodes. Develop a scheme to network multiple nano-radio nodes. The demonstration will initially use two nano-radio nodes, but eventually be scaled to at least 4 nodes. The networking scheme must also provide a path for scaling to a large number of nodes.

PHASE III DUAL USE APPLICATIONS: It is expected that these nano-radio systems will have applications in wide ranges of wireless sensor networks and micro autonomous systems. Phase III work will develop self-assembled and reconfigurable network architectures to connect many of these nano-radio nodes. These networked THz nano-radio nodes can be incorporated into current Army and DoD programs in sensor networks and micro autonomous systems integrated with sensing, computation and navigation capabilities to enable stealth and collaborative information gathering in adverse and hostile battlefield environments to achieve enhanced situational awareness for the Soldiers. Low fabrication cost of CMOS technology also means THz nano-radio technology can easily be transitioned for commercial applications where many inexpensive communicating nodes are required, e.g. Internet of Things.

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KEYWORDS: terahertz communications, sensor network, micro autonomous system, CMOS technology, integrated circuit, nano-radio

A15A-T006 TITLE: <u>Novel Lightweight Thermoacoustic Materials and Processes for Noise Cancellation of Military Ground Combat Vehicles (GCV)</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective of this STTR is to develop a lightweight thermoacoustic device based on novel materials for noise cancellation of military ground combat vehicles (GCV) (a thermally driven thin film material that will generate sound pressure from a supplied alternating current modulated in the audio frequency range from 20 to 20 kHz.).

DESCRIPTION: Acoustic phenomena can be observed in certain materials (e.g. graphene) when they are electrically heated with alternating current while free-standing or supported by a substrate. Such materials with small heat capacity per unit area possess outstanding thermoacoustic properties and can be used as a thermally driven thermophone (e.g. loudspeaker) [1]. Arnold et al. developed the theory of the thermophone and described the behavior such that as current is passed through thin conducting materials periodic heating sets up temperature waves that propagate into the surrounding medium[2]. This mechanism is carried out through joule heating which heats up the air above the surface, thereby producing sound waves from periodic air vibration. It is important to note, that this material produces sound from the thermal expansion and contraction of the air in the vicinity of the thin film, and not from the mechanical movement of the thin film. This thermal contraction and expansion of the surrounding medium determine the amplitude of the resulting sound waves [2]. The criteria for a good thermophone is that the conductor must be thin, with a heat capacity that is small, and it must be able to conduct to its surface the heat that is produced in its interior [3].

Researchers have proven that thin film thermoacoustic materials can be used for bench-level loudspeaker applications [3-7]. Hence, incorporating thin lightweight materials in small spaces would be an ideal solution for vehicle noise cancellation for military GCV engines. The lightweight thin film geometry can be easily designed to fit into tight spaces and attempt to cancel engine noise by generating an identical signal that is 180 degrees out-of-phase with the detected signal (noise). In military settings, engine noise can be a source of vulnerability, revealing the location of vital resources to hostile threats, by mitigating such threats this technology will provide for enhanced soldier protection. Current noise cancellation systems are capable of reducing steady state noise by 5-10 dB at frequencies up to few hundred hertz. Thin film thermoacoustic loudspeakers are lightweight and have a geometry that can be easily designed to fit into tight spaces. The proposed thermoacoustic thin film technology has the likelihood of providing for an enhanced acoustic or noise suppression system to the Army’s future GCVs.

PHASE I: Proposers should identify potential novel 2 dimensional materials that would qualify as good thermophone candidates. The offerers should process materials, design and fabricate an encapsulated thin film thermophone and thereby investigate thin film loudspeaker material properties such as the generated sound pressure levels and frequency dependencies of the amplitude of the acoustic signal. The Phase I work should also include thermal imaging, thermal conductivity measurements, heat capacity per unit volume measurements, an evaluation of the thermal interfaces, measure the sound pressure as a function of the input power and achieve sound pressure levels upwards of 120dB.

PHASE II: The small business should implement the processing innovations identified in Phase I to improve the thermoacoustic properties of the materials and develop a methodology for achieving sound pressures in the range of audible sound 60-140dB. The proposer should incorporate an anechoic chamber to conduct sound measurements in order to mitigate ambient noise. Also, the offerer will demonstrate a prototype device that incorporates the thermoacoustic thin film into a digital and analog communications system with a sufficient bandwidth.

PHASE III DUAL USE APPLICATIONS: The offerer will develop a manufacturing process and reproducible scalable thin film thermophone. The lightweight thin film geometry can be easily designed to fit into tight spaces and attempt to cancel engine noise by generating an identical signal that is 180 degrees out-of-phase with the detected signal (noise). The proposed thermoacoustic thin film technology should be capable of reducing steady state noise by 5-10dB or better.

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KEYWORDS: Thermophone, thermoacoustic, acoustic device, thin film loudspeaker

A15A-T007 TITLE: Compressive 3D Infrared Imaging

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop and demonstrate a compact 3D imaging system based on compressive sensing to measure 3D coordinates and photorealistic texture at a video frame rate.

DESCRIPTION: There are two major approaches to obtaining 3D photorealistic information of the world: one using software-based fusion of simultaneous visual images and LADAR scans and the other using stereovision or multiframe-based reconstruction. Systems based on the first approach operate in point-by-point scan mode and are difficult to achieve high frame rates for real-time applications [1, 3]. On the other hand, stereovision systems can provide both dense point clouds and texture [2], however, their accuracy for 3D measurement and frame rates are limited by the environment, quality of calibration, and modeling of camera positions [4, 5]. These systems are also bulky and expensive. Recent research has shown the potential of 3D imaging based on the compressive sensing framework [6]. This new approach exploits the sparsity of image or video data and computationally reconstructs 3D information from a series of 2D infrared images at different perspective views, potentially leading to significant weight, size, and cost reductions for 3D infrared imaging capabilities. For many important military applications such as vision-based robotic navigation and autonomous indoor exploration, the availability of a compact sensor that can provide 3D photorealistic imagery is critical to mission success.

This STTR topic seeks the development and demonstration of a low cost, compact infrared imaging system that can generate high quality 3D information with photorealistic textures of a scene at video frame rates (30 fps or higher). The system should be compact and light weight (comparable with an ordinary digital camera) so that it could be mounted on top of a small robotic platform. In addition, it should be suitable for both day and night operations, particularly for autonomous indoor exploration. The video data should provide geometric, textural, and depth information of the detected objects.

PHASE I: Phase I effort should be directed toward preliminary system design and proof of feasibility. Proposed solutions should be aimed at obtaining the highest possible quality of 3D infrared images. Incorporation of an active infrared laser is expected for high precision depth sensing. Detailed theoretical and experimental analyses of the proposed system based on cost, schedule, technical performance and risks should be performed and documented. Potential issues and challenges should be identified with constructive plans to fully resolve them in Phase II. Any algorithms needed for Phase II should be in place and validated.

PHASE II: Effort should focus on building a prototype of the 3D imaging system and demonstrate its utility via field-testing in representative operational environments. Tasks should also include evaluation of the efficiency, reliability, maintainability, and manufacturability of the system. Further improvements in algorithm or hardware design should be performed as warranted to achieve a satisfactory performance level.

PHASE III DUAL USE APPLICATIONS: Effort may focus on further developing the capability for transition to military C4ISR programs through defense laboratories (such as the Army Research Laboratory) or to commercial defense companies such as FLIR Systems or Lockheed Martin. Such 3D photorealistic imaging capabilities will find many important military applications including navigations of unmanned ground systems, indoor exploration, and battlefield situation awareness. Civilian applications are facility protection, search and rescue, and industrial automation.

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KEYWORDS: compressive sensing, 3D imaging, range sensing, stereo vision, infrared imaging

A15A-T008 TITLE: EMS Monitor & Broadcast Training Capacity Enhancement

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The electromagnetic spectrum (EMS) is one of the most valuable assets of a battlefield commander, and unimpeded use of the spectrum is a prime objective. The EMS will routinely be congested and contested in future combat scenarios challenging spectrum dominance and control. There is a strong need for a low-cost, man-packable device that can emulate anticipated opposing force broadcasting and blue force EMS monitoring capabilities for enhancing war fighter training.

DESCRIPTION: Advances in modern electronic communication signal processing algorithms coupled with advances in devices technologies from analog, digital to software create new dynamic battlefield conditions including congested, contested and dynamic spectrum sharing environment. These new conditions make realistic war fighter training imperative. We cannot expect to win in an operational environment unfamiliar to joint forces.

These modern communications technologies employ complex and adaptive behavior including waveforms at the physical level. These waveforms can be broadband with very low power spectra density. Several communication channels can use the same spectral allocation through Spread Spectrum techniques, Multi-Carrier Modulation or dynamic spectrum access methods. Since these next generation waveforms will be dynamic and adapt in real time, it might be extremely challenging to differentiate between blue and red waveforms which can lead to fratricide. To address these technology challenges and properly train our systems, we must develop an advanced, man-packable EMS monitoring and broadcast capability.

In spite of potential ineffectiveness of many conventional electronic warfare methods in the modern environment, new EMS monitoring and signal processing approaches may provide a means by which modern communications in future battlefield environments can be successfully monitored and broadcast [1-4]. The objective of this research is to show new techniques can make advanced EMS monitoring and broadcasting possible. The device under development should be able to monitor advanced communication waveforms in congested and contested environments and classify the waveforms. The desired EMS monitoring capabilities includes agile/adaptive and software defined waveforms, networks, blue/red classification and behavior or intent identification. Based on discovered information, the developed device should be able to execute an optimal broadcast strategy.

The device under development should employ an open platform principle, so the new methods can be implemented easily. It is expected that research will fully utilize a software defined radio (SDR) paradigm. Only commonly available tools and languages should be implemented.

To understand behavior and performance, the new algorithms for the device under development must be evaluated in the laboratory in a realistic environment which is representative of future battlefields. The environment must be fully instrumented, controllable and repeatable, and also faithfully represent the expected congested and contested conditions.

PHASE I: In Phase I, the offeror will research techniques for radio signal detection and electronic warfare and propose a signal processing, hardware, and software solution for the training equipment. In particular, the offeror will:
• Investigate analytic models, simulation and analysis of present and futuristic broadcast waveforms;
• Investigate spectrum monitoring techniques to detect, ID and classify present and future waveforms in congested and contested RF environment;
• Conduct computer simulation of developed spectrum monitoring method for advanced communication;
• Evaluate developed monitoring and broadcasting methods in the laboratory in the context of expected future RF operating environments;
• Adopt or design open system SDR methodology including Integrated Development Environment (IDE) with extensive SDR library.

The output of Phase I should be a SDR design, including proposed hardware and software framework. In addition, the proposed techniques for both the spectrum monitoring and broadcasting methodology should be documented.

PHASE II: In Phase II, signal monitoring and signal synthesis research will be completed and techniques will be finalized as well as the hardware and software architecture. A prototype will be built based on Phase I that can accommodate most common military communication waveforms. The prototype does not necessarily have to be a man portable device, but a clear path to this form factor must be identified. It should be tested at a final demonstration in order to access its capabilities and performance. Best software practices, including documentation, should be adhered to and standard tools and languages used in order to facilitate modifying to incorporate future waveforms and techniques.

PHASE III DUAL USE APPLICATIONS: Develop specific product in a man-pack form factor from the prototype design. Work with customer to identify additional capabilities based on the latest waveforms and techniques. Create a capabilities document including operating procedures and methodologies.

Potential dual use applications include monitoring of commercial bands for unauthorized users and testing of interference with commercial transmissions.

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KEYWORDS: Spread spectrum, spectral sensing, RF monitoring, spectrum dominance

A15A-T009 TITLE: Compact Integrated Ion Trap Quantum Systems

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Innovate, develop, demonstrate, and commercialize a compact integrated ion-trap quantum system needed for the high-performance operation of ion based quantum sensors, clocks, and other precision measurement systems. The platform will serve as a foundational block upon which quantum technology applications can be implemented through interchangeable ion-trap chips and associated design elements.

DESCRIPTION: Recently several basic research advances (Refs. 1-7) have been made in ion-trap quantum systems that have significantly improved the performance of these systems. These research advances include (a) micro-fabricated surface ion traps; (b) cryogenic traps that have significantly reduced anomalous ion heating; (c) all glass optical cells for atomic systems; (d) in-situ ion trap surface cleaning techniques; (e) elimination of traditional large vacuum systems; (f) high-density ion trap chip wiring; among others. In combination, these advances provide the opportunity to develop high-performance integrated ion-trap quantum systems. In turn, such integrated systems could significantly speed the development of applications of atom and ion-based quantum technology by reducing the design-develop-deploy cycle execution time, providing a robust chip interface, and simplifying system design. This would importantly provide greater access to this emerging technology and, therefore, allow for an expansion of explorations of quantum information processing, quantum computing and applications for quantum science.

There are several technical challenges facing the practical integration and miniaturization of the recent advances that must be addressed. Further research and development is needed before potential solutions can overcome these challenges to integration. Integrated designs must incorporate sufficient flexibility for existing and future ion chip trap technologies, must provide a high degree of optical access covering a wide range of wavelengths that can span the near ultra-violet to the near infra-red, incorporate an oven and delivery mechanism providing the ion species of interest, and must provide a large number of feedthroughs of different types (low voltage, low power, RF, among others) needed for operating a complex ion-trap system. Further, feedthroughs to support oven operation and fiber optics should also be considered in the design. Ultrahigh vacuum must be maintained in a miniature vacuum system. Many applications require very high quality optical surfaces. Low residual magnetic fields are needed for magnetic sensor applications. Recent research has also shown that clean chip surfaces are critical and may require in-situ cleaning. Integration of in-situ cleaning technology with the package may be required for compactness and operability.

PHASE I: Innovations are needed in design to incorporate and optimize recent advances in ion-trap quantum systems to develop a high-performance compact integrated ion-trap quantum system. Effort should focus on design and proof-of-concept demonstration of critical system components comprising an integrated optimized design, including ultrahigh vacuum packaging technology occupying small volume with high optical access, standardized ion-trap chip carriers, associated feedthrough wiring for full operation of an ion-trap chip, in situ chip cleaning, and associated components for ion chip-based quantum technologies. Modeling and simple experiments should be performed to demonstrate feasibility of the proposed approach. An example application of trapped ions should be identified and used for the proof-of-concept demonstration.

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

PHASE III DUAL USE APPLICATIONS: The integrated system developed in Phase II will provide a versatile platform for the successful development and demonstration of quantum sensors, quantum computing, and other precision measurement systems based on ion chip traps. Potential customers include researchers in universities, industry, DoD laboratories, and DoD contractors and system integrators. Partnerships with system integrators developing gravity gradiometers, timing systems, navigation systems, and similar such sensor and measurement systems is another Phase III avenue. Other Phase III opportunities include the leverage of IP generated from component technology for other applications requiring operation in ultra-high vacuum and/or requiring high optical access. Further commercial applications could include the mining industry.

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KEYWORDS: ion traps, surface traps, quantum sensors, quantum computing

A15A-T010 TITLE: <u>Lithium Ion / Super Capacitor Hybrid System</u>

TECHNOLOGY AREAS: Materials/Processes

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 solicitation.

OBJECTIVE: Develop new hybrid lithium ion battery / super capacitor energy storage devices that are safe and have high power capabilities.

DESCRIPTION: Lithium-ion batteries generally have excellent high-rate charge and discharge capabilities, however, as these batteries approach full state-of-charge the charge and discharge rates can be negatively impacted. In addition, lithium plating at a high charge rate is a safety concern due to the formation of dendrites that can lead to catastrophic failure. This can lead to oversizing batteries and increased solider burden to allow their use in challenging applications with high charge and discharge rates. New hybridized energy storage systems that incorporate a capacitor function offer an approach to circumvent these limitations. This will lead to approaches to combine a lithium-ion battery with an ultracapacitor to form a battery/super capacitor hybrid system to meet military and commercial markets where high rate charge and discharge are required, especially for repetitive pulse power applications. Currently there are several studies of such hybrid systems, with the major challenges being cost, safety and energy density. This topic is to encourage development of new concepts to address these concerns, as well as to increase cycle life. Such a hybrid system should have the potential to reach >10 times of the energy density of the super capacitor alone (5 Wh/kg).

A prototype for the proposed hybrid system should have a capacity of at least 0.5Ah, and there should be a relatively straightforward path to larger systems.

PHASE I: Design, construct, and evaluate proof of concept device with a capacity of 0.5 Ah, and an energy density of 50 Wh/kg that has improved safety over existing systems. Show a technical pathway to achieve the phase II goals.

PHASE II: Demonstrate and deliver full-sized system (10 Ah) with energy density of 100 Wh/kg and evaluate the performance of the device in specific applications.

PHASE III DUAL USE APPLICATIONS: Development of devices for both civilian and DoD use. There are many electronic devices used in the civilian community (including law enforcement and first responders) that would benefit from energy storage devices with improved charge / discharge capabilities and enhanced safety including mobile electronics especially radios that consume much more power when transmitting. Additionally cell phones are another device with dramatic changes in energy consumption over time.

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KEYWORDS: lithium ion battery, energy storage, hyrbridized, capacitor, super capacitor, ultra capacitor

A15A-T011 TITLE: <u>Advanced Fibers for High Efficiency Capture and Release of Human Cellular Material for Forensic DNA Analysis</u>

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: USASOC

OBJECTIVE: Develop a fiber that can capture human cellular material with high efficiency from a variety of surfaces and then release the captured cellular material with greater than 95% recovery upon introduction of an external stimulus (e.g., a biological, chemical, thermal, electrical, optical, or mechanical stimulus).

DESCRIPTION: The device most commonly used for collection of cellular material for forensic analysis is a simple sterile cotton swab. The cotton swab is simple to use, inexpensive, and can be used for a wide range of biological materials (e.g., saliva, blood) and substrates (e.g., wood, metal, fabric). Some published studies have demonstrated that a cotton swab is the overall most efficient collection tool for forensic samples [1-2], while others have suggested using a variety of swab types (e.g., cotton, foam, nylon) depending on the sample type and substrate [3]. It has also been demonstrated that the sampling efficiency (sample capture from the substrate) and extraction efficiency (yield of sample release) of collection devices often differ, thereby resulting in a loss of valuable material required for downstream forensic DNA analysis. At least 100-200 picograms (~20-40 cells) of extracted DNA is required for forensic DNA typing, thus inefficient sample recovery from a surface or cell entrapment within swab fibers is particularly problematic for forensic samples where the amount of recoverable material is at trace levels. This issue is further compounded by inefficiencies encountered with the methods commonly employed by forensic laboratories to extract DNA from human cells. Studies have shown that during the DNA extraction process approximately 50-80% of the initial sample is also lost [4].

The goal of this topic is to develop a fiber with binding properties and/or physical structure that can be controlled to initially support high efficiency binding of low abundance human cellular material, and then be triggered to release the bound cellular material with near absolute recovery in less than 15 minutes. The composition and properties of the fiber, as well as the treatment used to trigger recovery of the captured cellular material, must be compatible with the standard methods used in forensic laboratories for DNA genotyping (e.g., organic or automated bead-based extraction techniques, quantification methods, PCR amplification, capillary electrophoresis) [5]. The fiber must be free of human DNA, stable at room temperature, not degrade or react with the collected biological material, and exhibit a shelf life for use in forensic collection of at least one year with no loss of activity or efficiency.

PHASE I: Develop a fiber that captures human cells with > 95% efficiency over a wide range of cellular input levels (25,000 – 400,000 cells) and a method/treatment which controllably releases > 80% of the bound cellular material in less than 1 hour. Demonstrate that the composition and properties of the fiber, as well as the treatment used to recover the cellular material, are compatible with the following standard forensic DNA extraction procedures: manual organic extraction, spin-column extraction, and bead-based extraction.

PHASE II: Optimize the fibers to demonstrate capture of > 99% of human cells from a minimum sample of 500 cells and > 95% recovery of the cells in less than 15 minutes using triggered release. Formulate the fibers into a format that is compatible with standard forensic collection (e.g., a swab) and demonstrate that fiber strength is sufficient to maintain integrity during standard forensic collection processes. Perform a DNA extraction efficiency study using either standard forensic DNA extraction procedures (manual organic extraction, spin-column extraction, and bead-based extraction) or an alternative extraction method that reproducibly recovers at least an equivalent amount of DNA compared to the three standard methods, and demonstrate a reproducible DNA recovery efficiency of at least 75% starting from cell capture using the fiber collection device through to DNA extraction from the recovered cells. The DNA extraction efficiency study must examine a wide range of cellular input levels (500 – 400,000 cells). Demonstrate capture of > 99% of human cells from a variety of wet and dry material surfaces, including at a minimum metal, wood, plastic, glass, cloth, and adhesive tape. The material surfaces must include combinations of porous/nonporous and smooth/rough surfaces. Integrate the triggered release treatment into the standard forensic DNA typing workflow (from recovery of cellular material from fibers, to DNA extraction from the recovered cells, to capillary electrophoresis for DNA fragment analysis) and demonstrate no interference of the fibers or the cellular capture and release process with any step of the forensic DNA typing process. Assess scalability and cost of the overall process of fiber production and treatment to release captured cells. Provide 200 collection devices (e.g., swabs) to the Army for independent testing.

PHASE III DUAL USE APPLICATIONS: The development of an advanced fiber for high recovery collection and release of forensic biological samples will increase the reliability of genomic forensic analysis and enable the extraction of actionable forensic information from evidence with limited cellular material. The civilian sector would also significantly benefit from the developed technology and could transition for use in federal, state, and local forensic laboratories, as well as the medical sector where the collection of biological specimens is routine for clinical diagnostics.

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KEYWORDS: fiber, swab, DNA, forensic

A15A-T012 TITLE: Robust Training System for Autonomous Detectors

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The objective of this STTR is to develop a simple, rugged, and robust system for rapidly training small animals to reliably detect and report odors of explosives or other items of interest.

DESCRIPTION: The Army is engaged in extensive humanitarian demining efforts. Demining is often necessary to restore farm land to agricultural use, and to enable societies to stabilize after war. Although dogs are the most commonly used animal for mine detection, it has been demonstrated that other animals can reliably smell odors emitted by buried explosives, and smaller animals can complement canine detection capabilities in some situations.

The cost of training animals to detect mines or explosives is strongly correlated with the amount of human time required. Both rats and dogs take months to train and a fully trained and certified animal will cost tens of thousands of dollars. It is desirable to have a simpler, rugged, robust, fast, and low-cost system for training animals to detect and report specific odors, such as those released by a buried mine or IED.

PHASE I: The investigators will develop new approaches to quickly and efficiently train rodents to detect and report the presence of specific odors. The successful team will consist of not just engineers but will thoroughly incorporate experts in psychology, animal training, and learning. At the end of phase I the team will present detailed plans for the training approach, along with preliminary data demonstrating the feasibility of the approach. Phase I results will be evaluated on simplicity, speed, robustness, cost, and effectiveness.

PHASE II: The investigators will design, build, test, and refine their system, demonstrating their ability to rapidly train animals to detect specific odors. The system will include the ability to rapidly validate each animal's performance each day, and will provide daily data on each animal's error rates, both false positives and false negatives.

PHASE III DUAL USE APPLICATIONS: The investigators will produce and sell large numbers of these systems to the U.S. DoD, law enforcement agencies, TSA, intelligence agencies, search and rescue organization, and humanitarian demining NGOs. Mines are widespread throughout much of Africa, Asia, and Central America and demining operations are expected to continue for decades. Finding and removing mines is necessary to restore mined land to civilian use. Other uses include screening individuals and luggage for explosives, finding IEDs, and locating living and dead humans after natural disasters such as earthquakes, tsunamis, and mudslides.

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KEYWORDS: detection, IEDs, mines, canine, rodents, rats, dogs, learning, training

A15A-T013 TITLE: Multiple Antenna Element Approach to a Combined Precision Attitude Determination and GPS Anti-Jamming/Spoofing Capability

TECHNOLOGY AREAS: 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 solicitation.

OBJECTIVE: The objective of this topic is to develop an innovative GPS multiple antenna element approach to continuously provide a combined solution for precision attitude (azimuth and elevation) and detect, mitigate and geolocate RF sources of jamming and spoofing.

DESCRIPTION: GPS interferometry [Ref. 1] is used for precision attitude determination (azimuth and elevation) for a number of tactical systems (including Long Range Scout Surveillance System (LRAS3) [Ref. 2] and Persistent Threat Detection System (PTIDS) [Ref. 3]). A GPS interferometry system uses GPS signals to determine attitude (azimuth and elevation) by measuring the phase received at multiple antennas to determine orientation. In the same manner a multiple antenna system could be configured to determine a azimuth and bearing to an RF signal, which could be further used to detect whether the signal is a jammer or a spoofer.

Under this topic a system will be designed and developed using a multiple antenna element technique applicable to continuously provide precision attitude data, when GPS is available. And during times of GPS denial the same system will be used to detect, mitigate and geolocate sources of the jamming and spoofing signals. Applications to be explored include ground vehicles and low dynamic aircraft. A low-cost and low size, weight, and power (SWAP) solution is key to broad Army application. Proposals in this regard will need to consider the issues and elaborate on solutions related to phase and group delay errors/variations introduced by the use of a multiple antenna system such as a Controlled Radiation Pattern Antenna (CRPA) [Ref. 4, 5 & 6], which raises concerns for antenna induced biases resulting in the degradation of the accuracy of GPS metrics (position, velocity and timing) as well as GPS interferometric attitude determination.

Alternative solutions for providing a low cost, low SWAP combined attitude and anti-jam/spoof capability are also encouraged.

PHASE I: Phase I of this topic will be a feasibility study and preliminary design for the Combined Precision Attitude Determination and GPS Anti-Jamming/Spoofing Capability. This study should investigate how the accuracy of a multiple AJ antenna system, such as a CRPA, will affect GPS metrics (position, velocity and timing) as well as GPS interferometric attitude determination. The study will also determine potential performance characteristics of the anti-jamming/spoofing capability, considering several tradeoffs, and implementation on ground vehicles and low dynamic aircraft.

The Phase I deliverable will be a final report delineating a feasibility study and preliminary design efforts documenting the six months of effort. It should analyze the GPS and GPS interferometric metrics for various multiple antenna element solutions including CRPA-based anti-jam antennas (three to seven elements, of varying wavelength spacing). The analysis should also consider diverse distributions of jamming and spoofing sources locations. Finally the report should state the requirements and a preliminary design for the prototype system to be developed in Phase II.

PHASE II: Conduct the design, development and construction of a prototype Combined Precision Attitude Determination and GPS Anti-Jamming/Spoofing Capability, which demonstrates in a laboratory environment the capability to provide accurate attitude and the ability to detect, mitigate and locate sources of jamming and spoofing. Use of GPS simulators and laboratory signal generators to simulate jamming and spoofing will be used for this phase. Deliverables of Phase II will be the prototype system and a final report delineating a plan for Phase III for a full scale development for the maturation and validation and verification (V+V) of these capabilities to assist transition to the envisioned final product for application on various identified Army platforms. Finally, the report will include lessons learned of the work performed in Phase I and Phase II.

PHASE III DUAL USE APPLICATIONS: Finalize the Combined Precision Attitude Determination and GPS Anti-Jamming/Spoofing Capability system development. Develop and implement a technology transition plan for consideration of the Product Director Positioning Navigation and Timing (PD PNT) in cooperation with implementing platform program managers, having applicability to the US Army and other DoD users that require Assured PNT capability. Also, this technology is commercially applicable to providing applications requiring precise PNT and attitude information and/or the detection and mitigation of jamming and spoofing, such as transportation (airline, trucking, trains, etc.), tracking of shipment containers, communication and network synchronization and power line transmission.

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KEYWORDS: Assured PNT, GPS, interferometry, jamming, spoofing, attitude, multiple antenna, CRPA

A15A-T014 TITLE: Scaling & Supramolecular Engineering of Metal-Organic Frameworks (MOFs)

TECHNOLOGY AREAS: Chemical/Bio 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 solicitation.

OBJECTIVE: The two major objectives of this topic are (1) to develop techniques for scaling a variety of metal-organic frameworks, to include flow-through systems and/or solvent recycle, to multi-kilogram quantities, and (2) to develop techniques for supramolecular assembly, with a focus on self-assembly, to form engineered structures, such as granules and arrays, through polymerization and/or other means. Specific MOFs of interest include, but are not limited to, CuBTC (aka HKUST-1), UiO-66 analogs, and MIL-MOF analogs. For the former objective, scaling should focus on single batch (or continuous flow) quantities greater than 1 kg, with associated costs less than $250/kg, with an objective cost even lower. Revolutionary concepts are sought to lower the price to be competitive with activated, impregnated carbon.

DESCRIPTION: Metal-organic frameworks show promise for military applications in that they can be tailored with a variety of porosities, functional groups, and metals. Despite this promise, however, maturation of MOFs has proved prohibitive due to the high cost of scaling as well as the ability to engineer them into functional forms. To study the latter, sufficient quantities of MOF must be efficiently synthesized. Once formed, we envisage that MOF superstructures can be achieved in a number of ways to promote engineered particles. Incorporation of a polymer architecture containing multiple reactive moieties can lead to linking of MOF crystals via the formation of covalent bonds (i.e. isocyanate-functional polymers with amine-functional MOFs). Alternatively, supramolecular interactions between a hydrogen bonding or chelating polymer and the MOF can be employed (i.e. catechol-functional polymers) through non-covalent interactions with unsaturated metal sites. Another strategy involves the use of a polymer chain that acts as a passive structural support where chain entanglements provide structure to the composite. We propose that linking of MOF crystals in situ will lead to MOF-based structures that are more amenable to advanced processing leading to useful engineered forms.

Current efforts have demonstrated the ability to synthesize batches of MOFs in 100-gram quantities, but methods are not known for scales above 1 kg. The current state-of-the-art method for engineering MOFs is to use pressure to form pellets,[1, 2] or to use binders.[3] Forms other than powders are currently being investigated, and it is anticipated that using solution techniques, large pellets can be developed in-situ during synthesis or directly following MOF synthesis. Furthermore, many MOFs are unstable after synthesis, and methods for stabilizing MOFs against moisture are sought. Bench scale chemistry in conjunction with molecular modeling may be required at the academic level to identify proper paths forward.

PHASE I: Demonstrate the ability to synthesize CuBTC and UiO-66 or UiO-66-NH2 to 100 gram batches, to include activation. Provide materials to ECBC in an engineered form that does not significantly (> 10%) reduce the performance of the engineered form as compared to the baseline powder. Identify and scale other novel MOFs for potential scaling with activity towards toxic chemicals.

PHASE II: Scale the process from Phase I to 1+ kg quantities with no decrease in performance as compared to smaller scales. Reduce cost associated with process. Provide 10 kg of material to ECBC for evaluation. Further expand ability to synthesize other MOFs and engineer particles. Develop a commercialization strategy.

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. Incorporate materials into other forms. Work with Federal Laboratories (e.g. U.S. Army Edgewood Chemical Biological Center) to incorporate into military filters, and identify companies with respiratory protection programs (e.g. 3M, Scott, etc.) to transition materials for industrial and First Responder applications. Potential dual-use applications include, but are not limited to, oxygen storage for medical applications, carbon dioxide scrubbing for flue gas remediation, ammonia removal in hospitals and fertilizer plants.

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KEYWORDS: Metal-organic framework, scaling, supramolecular structures

A15A-T015 TITLE: Antisense Treatment for Middle East Respiratory Syndrome Coronavirus (MERS-CoV) Infection

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Design, develop, and deploy an antisense agent for the treatment of individuals infected with MERS CoV.

DESCRIPTION: The Middle East respiratory syndrome coronavirus (MERS-CoV) is a positive-sense, single-stranded RNA virus in the beta coronavirus group, Betacoronavirus lineage C. The MERS-CoV are divided into two clades, the initially identified clade A, and the more recently identified and genetically distinct clade B. As of June 11, 2014, 699 laboratory confirmed cases of human infection with 209 deaths have been reported to WHO (1). The median age of cases in Saudi Arabia is 46 years old and more than 25 percent of reported cases are health care workers. Dromedaries are the likely source of the virus as genomes from MERS CoV recovered from dromedaries are 99.9% identical to human clade B MERS CoV. Most of the cases reported from Saudi Arabia have been acquired through human-to-human transmission in health care settings.

No current approved therapy for treatment of MERS CoV or the earlier SARS CoV exist. Pre-existing antibodies are not effective. A modified vaccinia virus Ankara engineered to express MERS CoV spike protein appears to be a suitable vaccine candidate (2). In vitro screening efforts have identified cyclosporine A and type I interfereon (3) and screens with SARS identify ACE2, cathepsin L and entry inhibitors in the low uM range have been identified (4). Current efforts in the design of therapeutic antibodies are also in progress. The objective of this proposal is to develop an antisense inhibitor of the MERS CoV.

In a large collaboration, we have developed antisense antivirals for hemorrhagic fever viruses (5-7), influenza A (8), and coronaviruses (9). The development path involves evaluation of a small number of antisense oligomers in cell culture models of infection to observe reduction in viral cytopathic effect, reduction in viral replication by measuring plaque numbers, and expanding the dose-response curve to identify the cytotoxic concentration. Small animal models will be employed such as the bat coronavirus strain HKU5 (Agnihothram et al., 2014) to observe antiviral activity in an inexpensive animal model. Finally, the rhesus macaque model (10) will be utilized for advanced development and potentially for pivotal efficacy trials.

PHASE I: Synthesize antisense agents with novel oligomer chemical structure and conduct in vitro experiments to demonstrate MERS CoV antiviral activity, evaluate potential cytotoxicity and specificity, investigate oligomer stability, and improve methods for oligomer synthesis. Demonstrate efficacy in a small animal model infected with a MERS CoV prototype virus.

PHASE II: Determine the maximum tolerated dose (MTD), develop analytical methods for quantitation in biological fluids and tissues and evaluate pharmacokinetics of the agent identified in Phase I. Demonstrate efficacy in a nonhuman primate model of MERS CoV infection to establish the optimal dose regimen, potential for MERS CoV resistance, and the human equivalent dose (HED). Arrange for preliminary interactions with the FDA and submit a pre-IND with plans for preclinical toxicology studies and the regulatory path to pivotal trial designs.

PHASE III DUAL USE APPLICATIONS: Submit IND application to the FDA and conduct a statistically significant safety studies in healthy volunteers and conduct pivotal efficacy studies in the MERS CoV NHP model for approval under the animal rule.

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KEYWORDS: MERS-CoV, antiviral, therapeutic, antisense, medical countermeasure

A15A-T016 TITLE: Conductive Transmissive Coating for Enhanced-Absorption Thin Film Solar Cells

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Research and develop an innovative coating for thin-film, lightweight, large-area flexible inorganic solar cells that will (1) transmit light, (2) provide a top conductive electrode and (3) scatter or trap light so as to enhance absorption. The coating must scatter long wavelengths into the thin solar cell and enhance the short-circuit current density, in order to increase the output power density and the power-per-pound ratio.

DESCRIPTION: The Army needs (1) thin-film, lightweight, large-area flexible inorganic solar modules, for solar blankets of interest to the Assistant Secretary of Defense for Operational Energy Plans and Programs (ASD(OEPP)),[1] the US Army Communications and Electronics Research, Development, and Engineering Center (CERDEC) and the US Army Natick Soldier Research, Development, and Engineering Center (NSRDEC), and for soft-walled Shelters and base power equipment developed at NSRDEC[2], (2) highly transmissive and conductive layers that are flexible and could replace Indium Tin Oxide (ITO) in these solar cells, and (3) enhanced absorption in these thin film solar cells, arising from light trapping and reduced reflectivity due to nanostructures, nanoparticles, nanowires, etc. Current solar blankets are composed of the materials, especially amorphous silicon and CIGS, described in Ref. 3. Critical metrics for solar blankets are output power density under full sun, total area, power output per pound, and cost. Thin, flexible, lightweight, flexible inorganic films can satisfy these metrics, if their module efficiencies can be improved by a factor of 1.7x.

We are seeking a novel coating, appropriate for thin film large-area lightweight inorganic solar cells such as those described in Ref. 3, that will scatter/trap light to better absorb long wavelengths and therefore improve Jsc by 25%.[4,5,6] This improvement to Jsc is expected to increase the efficiency of the solar cell, and therefore increase the watts/pound ratio towards the long-term goal of 1.7x improvement. We seek to replace ITO with a thin coating having a high visible and near-infrared transmission and conductivity. Innovative approaches involving nanostructures, nanoparticles, and/or nanowires, will be considered for this STTR topic. Proposals should consider novel methods for light scattering and not just a replacement of ITO with another film.

PHASE I: Research and develop an innovative coating that will improve the efficiency of thin-film, lightweight, large-area flexible inorganic solar cells. Consideration will be given to novel coatings for solar cells that function as a top electrode, transmitting/antireflective layer, and light-scattering/trapping layer, although other innovative coating-based approaches, that include light-scattering/trapping, may be considered. This light scattering/trapping must enhance absorption of long wavelengths that otherwise would be poorly absorbed by the thin semiconducting layer in the solar cell and/or better transmit than ITO in the near-infrared, and therefore will be expected to improve the short-circuit current density by 25% in Phase I. The analysis carried out in Ref. 3 suggests that such a coating for a monolithic cell ("monolithic" defined in Ref. 3) will have to exhibit low-resistivity (<10 ohms per square), and high transmission (>90% averaged across the visible). Demonstrate technical feasibility through modeling, analysis, and initial experiments.

Physical specifications:

- Short-circuit current density Improvement over AM1.5 (e.g. solar spectrum) integrated, commercial, large-area thin-film lightweight, flexible inorganic solar blankets, of interest to DoD, by a factor of 25%

- Weight > 20 W/lb (solar blanket)

- Cost No more than 10% above current ITO coating cost

- Wavelength-averaged absorption: Net improvement absorption (averaged over solar spectrum up to cutoff wavelength of solar cell) over commercial thin film solar cell

- Area > 1.8 m^2 (solar blanket)

- Fire retardant - In accordance with MIL-PRF-44103D

- Toxicity/mildew - In accordance with MIL-PRF-44103D

- Temperature range - In accordance with MIL-PRF-44103D

PHASE II: Carry through the Phase I proposal by fabricating/developing a conductive transmission coating layer, superior to ITO, that demonstrates absorption enhancement and, therefore, experimentally increases the short-circuit current and efficiency by a factor of 25% (e.g., 1.25x) when combined with a solar cell. Supply at least four solar cells, with total area more than 1 ft^2, that meets this short-circuit current density specification. Determine ways to integrate this coating into Army-fielded solar blankets. Illustrate a detailed path forward for solar blankets, with areas more than 1.8 m^2, that harvest more than 60 W/m^2 under full sun, and that can satisfy requirements for 33 W/lb and 60 W/m^2.

Test, characterize, and refine the performance of the conductive, transmissive, light-trapping layer in accordance with the goals in the description above. Deliver a report documenting the theory, design, component specifications, performance characterization, and recommendations for optimizing the absorption (conductivity, transmission, and light-trapping). Address manufacturability issues related to full-scale production for military and commercial utilization within applicable systems. Predict and optimize the usage cycle of the solar cell-enhancing layer; i.e., how many times the complete solar cell can be used in the field, without resupply.

PHASE III DUAL USE APPLICATIONS: Phase III will develop, through technology transition and/or commercialization, the full solar cell with enhancing layer, which must be manufacturable at a reasonable cost. In general, efficient conversion of solar energy into electrical energy is one of society's most important technological challenges, and solving this problem for the Soldier would enable commercialization of efficient, inexpensive solar energy for the general public. One commercial application is a higher-efficiency flexible rollaway that could be conveniently carried by outdoor recreationalists on extended trips, to charge batteries. Such technology could also be inserted into defense systems, such as man-portable Solar Blankets for the individual Soldier (see Ref. 1), wearable solar cells, or shelter-based solar cells.

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KEYWORDS: Solar Power, ITO, high-efficiency energy/power harvesting/scavenging

A15A-T017 TITLE: Fiber Based Materials for Energy Generation

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective of this topic is to explore and develop technology based on fiber materials that can generate energy for the direct use by the Warfighter for required electrically powered devices. This technology is envisioned to be part of the Warfighter garment system, effectively adding a power source with no additional weight.

DESCRIPTION: The Warfighter carries an ever increasing array of items requiring electrical energy. These items are currently powered with batteries that are either disposed or require recharging. Recent analyses by the Maneuver Center of Excellence and Communications and Electronics Research, Development, and Engineering Center have found that the average infantryman carries 11 unique battery types totaling approximately 16 pounds of added weight. The U.S. Army Training and Doctrine Command’s recent Operational Energy Concept of Operations cites additional data showing that batteries comprise 15-20% of the load carried by the average Soldier. Future capabilities in advanced sensors, networking and processing technologies will possess advanced low power electronics and power management features and will require innovative power source solutions. The trend towards more batteries and more battery-related weight is unsustainable.

Emerging operational concepts dictate the need for technology to support extended missions without the benefit of re-supply for 72 hours or longer. A recent analysis of the power and energy for the small unit reported the total Soldier power demand for a 72-hour dismounted mission Concept of Operation (CONOPS) to be 1320 W-hr for a Squad Leader, 605 W-hr for a Team Leader, and 578 W-hr for a Rifleman with most of the additional power requirement for the Squad Leader associated with communications equipment.

One solution envisioned through this topic is to develop and integrate fibers into the garment system a Warfighter must already wear to field generate power for direct use, recharging batteries or devices, or possibly storing the energy through a different process in the garment itself. Ideally, this solution will replace the fibers in the garment system with a power generating system that weighs no more than the system it replaces. Potential sources for this power include energy from the Warfighter environment (i.e., radiation, thermal, moisture) or energy from the Warfighter motion (i.e., kinetic). The fiber solution needs to convert energy from sources that exist to usable electrical energy.

A current fielded BB2590 rechargeable lithium ion battery provides 125 to 150 W-h/kg and weighs approximately 1.5 kg. A supply of batteries, or a means to recharge the batteries, must travel with the fielded Warfighter. The goal of this topic is to replace the energy of one of these batteries per day with energy obtained from the fiber solution (approximately 200 W-h per day) with little to no additional weight when compared to the base garment system. Other applicable information includes: the surface area of an adult is approximately 1.5 to 2 square meters; an Army Combat Uniform (ACU) weighs approximately one kilogram; peak solar radiation is approximately 1000 W per square meter.

PHASE I: The Phase I program must show the feasibility of the technical approach through a demonstration of the energy produced in field-realistic conditions for a small sample of the material. It is not necessary to demonstrate how this technology will be incorporated into a system (Phase II). A clear description of the required energy input and output needs to be provided along with the potential impacts on burden (weight, thermal) to the Warfighter. Phase I should show the proposed energy generation system to provide 50 W-h in a 24 hour period for realistic assumptions for Soldier activity and environmental exposure (i.e., kinetic devices can't assume 24 hours of constant motion, solar devices can't assume 24 hours of peak exposure, etc.).

PHASE II: The Phase II will scale the successful Phase I technology to a prototype system. The prototype system must incorporate the interconnects between the energy producing technology and the storage and/or use of the energy by the system. A clear demonstration of the energy produced by the prototype system for the set of field conditions used needs to be presented. Since this is a garment system, the practical requirements of the technology in terms of physical properties, durability, and launderability must be characterized. Phase II should show the prototype energy generation system to provide a minimum of 100 W-h in a 24 hour period for an actual field trial for the system.

PHASE III DUAL USE APPLICATIONS: Energy generation by fiber-based materials would have a broad base of applications. Military garments and collective protection would benefit from their inherent power supply to run communications, sensors, and thermal management with little or no additional weight. Any commercial application where an individual currently requires batteries for outdoor and mobile settings (phone, radio, computer, etc.) would similarly benefit from a fabric-based generation system. Current consumer smart phone devices require 5 to 10 W-h per day, an average laptop requires approximately 200 W-h per day. The technology from a successful Phase II prototype should be easily inserted into a simple consumer product to keep most communication devices charged.

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2. Energy harvesting: www.ntcresearch.org/pdf-rpts/Bref0610/F06-GT05-10.pdf

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KEYWORDS: Fibers, energy generation, energy harvesting, solar, piezoelectric, thermoelectric, electroactive

A15A-T018 TITLE: <u>Fuel Efficient Nanofluid Gear Oil</u>

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: Heavy Tactical Vehicles/TARDEC

OBJECTIVE: The objective of this research is to develop a Fuel Efficient Gear Oil using nanofluid technology.

DESCRIPTION: Power and energy are critical to the Joint Force's ability to conduct and support operations, enabling maneuver and freedom of action and providing operational reach and endurance. Energy and power enable decentralized force elements to conduct operations for extended periods of time and over extended distances. A number of studies and analyses have focused on the consumption rates for forces in theater and the fully burdened cost of fuel (FBCF). These studies and analyses have identified that the extremely high FBCF figures and high consumption rates result in a financial cost of fuel consumption by deployed operational forces that is a burden on the resources of DoD and the nation. Because the demand for the quantities of fuel being consumed by deployed operational forces are most often met by ground transportation, too many American lives are being risked to the threat of improvised explosive devices (IEDs). Future power and energy capabilities must lead to decreased demand and improved efficiency in order to reduce risk for the Warfighter, and to achieve greater independence from vulnerable logistics resupply. Reducing the demand for power and energy, along with the need for water will reduce the primary driver of sustainment volume and frequency. Improved power and energy capabilities will enhance mobility and maneuver by extending the range and endurance of the force and its security while decreasing the overall footprint and tempo of support forces.

Although highly effective, Army equipment consumes too much fuel. Powertrain frictional losses account for a large percentage of fuel energy that would otherwise be available to operate the vehicle. In addition, reducing frictional losses leads to further reductions in exhaust and cooling losses. Fuel efficiency of legacy equipment is difficult to improve without costly retrofits or reducing weight at the expense of armor. High viscosity fluids keep solid surfaces from contacting but also promote churning losses. Low viscosity fluids reduce churning losses but may not prevent solid-to-solid contact. Friction and wear are complex, system responses that generally cannot be fully resolved with simple bench tests, but full vehicle tests are expensive. New gear oils that increase fuel efficiency and are backward compatible with previous gear oils are needed so no equipment modification is necessary for their use.

Nanofluids are a composite system of nanoparticles suspended in a liquid. These fluids have been shown to exhibit excellent thermal properties including high thermal conductivity and beneficial tribological behavior such as reduction in friction and wear at much lower concentrations than conventional lubricant additives. However, the understanding of the underlying mechanisms for friction and wear of nanofluids is limited. Nanofluids with improved friction, wear, heat transfer, and extreme pressure characteristics due to the formation of superior tribofilms have the potential to produce a new class of lubricating fluids using lower viscosity base stocks, thus reducing the composite viscosity of the resulting nanofluid. In engines, this new class of lubricants could have the potential to increase fuel efficiency, enable an engine to run at higher operating temperatures, and increase the time between oil changes. In transmissions and gearboxes, such lubricants could be designed to improve efficiency and reduce wear, reducing both fuel consumption and the need for costly and time-consuming repair or replacement. New lubricant formulations would therefore enable the US Army's future vehicle systems to increase engine and powertrain performance and durability. It would also support Army units in the areas of system mobility, durability, reliability, survivability, and servicing to reduce the logistics cost burden. However, there is a wide variety of nanoparticle options for use in lubricants, each with their own advantages and disadvantages, and the underlying mechanisms that lead to nanofluid thermal, rheological and tribological performance benefits are currently lacking in literature.

The STTR topic is intended to solicit proposals that will develop new gear lubricants based on nanofluids. These new lubricants are expected to take advantage of the nanofluid properties to improve vehicle fuel efficiency and increase powertrain performance and durability.

PHASE I: Demonstrate friction and wear improvement beyond a TARDEC provided 75W-90 gear lubricant (up to five gallons) using a stable nanofluid consisting of nanoparticles suspended in a base oil. Stability is defined as the lack of change in concentration and size of the nanoparticles in fluid over time. The nanofluid must be stable for a minimum of one month. Conduct preliminary bench tests to characterize friction and wear performance of the nanofluid gear lubricant. Demonstrate that the nanofluid can be used in lower viscosity base stocks by providing protective films to prevent surface interaction and thereby allow improved gearbox and transmission efficiency by reducing churning losses without leading to increased wear in military vehicles. Perform cost estimates for production and the final cost of the product.

PHASE II: Demonstrate a fully formulated nanofluid gear lubricant that improves fuel efficiency by 2-3% without sacrificing component durability when compared to commercially available 75W-90 gear lubricants. The nanofluid must be stable for a minimum of one year. Accelerated 30 day storage stability must be verified in accordance to ASTM D7603. Perform a comprehensive evaluation of the efficiency, friction, and wear characteristics of this nanofluid gear lubricant using a motored full-scale gear test rig simulating a wide range of operating conditions and temperatures. From these tests, the potential fuel efficiency and durability in a variety of military vehicle systems can be correlated.

PHASE III DUAL USE APPLICATIONS: This technology has a broad range of potential civilian and military applications. This could ultimately lead to a fully formulated nanolubricant with superior rheological and tribological properties compared to current commercial and US Army lubricants.

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KEYWORDS: Gear Lubricants, Gear Oils, nanofluids