

ARMY

PROPOSAL SUBMITTAL

The United States Army Research Office (ARO), reporting to the Army Research Laboratory (ARL) manages the Army's Small Business Technology Transfer (STTR) Program. The following pages list topics that have been approved for the fiscal year 2006 STTR program. Proposals addressing these areas will be accepted for consideration if they are received no later than the closing date and hour of this solicitation.

The Army anticipates funding sufficient to award one or two STTR Phase I contracts to small businesses with their partner research institutions in each topic area. Awards will be made on the basis of technical evaluations using the criteria contained in the solicitation, within the bounds of STTR funds available to the Army. If no proposals within a given area merit support relative to those in other areas, the Army will not award any contracts for that topic. Phase I contracts are limited to a maximum of \$100,000 over a period not to exceed six months.

Based upon progress achieved under a Phase I contract, utilizing the criteria in Section 4.3, a firm may be invited to submit a Phase II proposal (with the exception of Fast Track Phase II proposals – see Section 4.5 of this solicitation). Phase II proposals should be structured as follows: the first 10-12 months (base effort) should be approximately \$375,000; the second 10-12 months of funding should also be approximately \$375,000. The entire Phase II effort should generally not exceed \$750,000. Contract structure for the Phase II contract is at the discretion of the Army's Contracting Officer after negotiations with the small business.

Army STTR Contracts may be fully funded or funded using options or incremental funding.

Please Note!

The Army requires that your entire proposal (consisting of Proposal Cover Sheets, the full Technical Proposal, Cost Proposal (using the template provided), and Company Commercialization Report) must be submitted electronically through the DoD SBIR/STTR Proposal Submission Website. A hardcopy is NOT required. Hand or electronic signature on the proposal is also NOT required.

The DoD-wide SBIR Proposal Submission system (available at <http://www.dodsbir.net/submission>) will lead you through the preparation and submission of your proposal. Refer to section 3.0 at the front of this solicitation for detailed instructions on Phase I proposal format. You must include a Company Commercialization Report as part of each proposal you submit however, it does not count against the proposal page limit. 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 Proposal Submission site. Please note that improper handling of the Commercialization Report may result in the proposal being substantially delayed and that information provided may have a direct impact on the review of the proposal. Refer to section 3.5d at the front of this solicitation for detailed instructions on the Company Commercialization Report.

Be reminded that if your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet therefore, do not include proprietary or classified information in these sections. DoD will not accept classified proposals for the STTR Program. Note also that the DoD web site contains timely information on firm, award, and abstract data for all DoD SBIR/STTR Phase I and II awards going back several years. This information can be viewed on the DoD SBIR/STTR Awards Search website at www.dodsbir.net/awards.

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Army STTR 06 Topic Descriptions

A06-T001 TITLE: Gaseous, Liquid, and Gelled Propellant Hypergolic Reaction Mechanisms

TECHNOLOGY AREAS: Air Platform, Space Platforms, Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Determine the differences and similarities of the hypergolic reaction mechanisms for gas/gas, liquid/liquid, and gel/gel bipropellant systems.

DESCRIPTION: Gelled hypergolic propellants offer safety advantages inherent to solid phase systems (good handling and storage characteristics, temperature stability, low vapor pressure) while offering performance characteristics similar to liquid phase systems (variable thrust, ability to throttle and turn on and off).

However, recent testing of liquid and gelled hypergolic propulsion systems has shown marked differences in ignition delay. Longer than anticipated ignition delays have been associated with engine failure.

The goal of this program is to elucidate the underlying physics and chemistry associated with ignition delay in hypergolic propulsion systems. More specifically, we are interested in determining if the differences observed in ignition delay for liquid and gelled hypergolic propulsion systems are due to mainly physical and/or chemical effects. We are also interested in the chemistry occurring during the initial mixing, and how the physical state influences early-time chemical reaction kinetics.

This information is crucial to understanding the overall hypergolic reaction mechanism of gelled propellants and to effectively design bipropellant engines.

Early bipropellant research suggested that physical state of hypergols may have an important effect upon the onset of chemical reaction. When liquid fuel and oxidizer drops approach each other, reaction occurs initially in the vapor phase exterior to the liquid propellant, and this early time vapor phase reaction may inhibit mixing by providing and expanding gas layer between droplets. Gelled fuel and oxidizer droplets/particles exhibit liquid like viscosities and transport, but because of their lower vapor pressures, gas phase reactions exterior to the gel may not provide enough energy to inhibit mixing. We would like to understand how this observed behavior influences ignition delay, and ultimately, engine performance.

This program has three parts. The first part will be to propose, after a thorough literature search, a detailed reaction mechanism for gaseous, liquid, and gelled hypergolic systems using Monomethyl Hydrazine (MMH) as the fuel and Inhibited Red Fuming Nitric Acid (IRFNA) as the oxidizer. Each mechanism should include the affect of the initial physical state of reactants (including gelling agents) upon chemical reaction rates important to ignition delay. Following the compilation of a proposed mechanism, a series of experiments will be designed to validate/invalidate all or part of the proposed mechanisms, especially those aspects that influence ignition delay.

The second part will be the identification of test methods and the design of the corresponding apparatus suited to measuring physical and chemical parameters important to mechanism validation, and to ignition delay, and the incorporation and benchmarking of analytical techniques to measure these physical and chemical parameters (e.g., time histories of combustor temperature, pressure, radical and permanent gases, etc.)

The third part will be to experimentally measure parameters during combustion, and compare the ignition transients of gas/gas, liquid/liquid and gel/gel propellants using MMH and IRFNA as the propellants and modify the mechanisms as experiment suggests. Ideally, we wish to understand how the proposed mechanism may be used to predict ignition delay in new gelled hypergolic propellant systems now under development.

PHASE I: Proposed mechanisms will be developed for the gas/gas, liquid/liquid/ and gel/gel hypergolic reactions of MMH and IRFNA based on literature search, previous research, thermochemistry predictions, and engine test results. Reaction mechanisms must include both physical and chemical effects so as to enable prediction of changing ignition delays for the different hypergolic systems being considered.

Following mechanism compilation, a set of test methods and apparatus will be devised that provides the best way forward in validating/invalidating the proposed mechanisms. Deliverables for the Phase I will be a summary of the known chemical kinetic information on reacting hypergolic systems, a proposed reaction mechanism for the gas/gas, liquid/liquid and gel/gel systems, and a summary of rate constants, thermodynamic parameters, and transport parameters (when known) for each step in the proposed mechanism. Additionally, a summary of analytical techniques, static and dynamic, that have been applied to hypergolic combustion studies will be used to propose a suite of instrumentation that will be used to validate the proposed reaction mechanisms. Finally, a design of recommended test systems suitable to the investigation of hypergolic reactions important to the proposed mechanism, and to ignition delay, shall be provided.

PHASE II: After selection of the test systems, a comprehensive test plan will be prepared for mechanism validation. This plan will include several test series. The initial test series will be used to benchmark the analytical instrumentation, and show the ability to measure ignition delay and chemical and physical parameters for a well characterized system. The first series will also be used to modify the test plan as needed. The second test series will be an initial attempt at measurements aimed at mechanism validation. The results of this first test series should comprise, at a minimum, a statistically significant set of time resolved measurements of ignition delay, temperatures, and chemical species important for each hypergolic system under consideration. Following these measurements, the final report will discuss whether the data support the proposed mechanisms for the MMH/IRFNA gas/gas, liquid/liquid/, and gel/gel systems. Using the experience gained from the investigation of IRFNA and MMH, preliminary mechanisms will be proposed for the hypergolic reaction of IRFNA with an advanced fuel, currently being developed, in the gas/gas, liquid/liquid, and gel/gel states and a single experimental test series will be performed to provide data towards validation of the proposed mechanisms.

PHASE III DUAL-USE APPLICATIONS: After a successful Phase II program, the small business can provide services to those companies who are developing liquid or gelled propellants and do not want to invest in building the capability to study hypergolic ignition and ignition delay themselves. This program is supporting the development of more effective and efficient gel propellant formulations; therefore, private industrial, NASA, and DoD propulsion applications would be ideal marketing targets. The emerging private space launch industry would be interested in this capability when evaluating novel ideas that would give them an advantage over traditional government launch services. This interest would be in actual space launch, satellite positioning, and, potentially, providing space travel to civilians. This emerging industry might be very interested in novel approaches to propulsion if they could be confident that their candidates would be hypergolic. Additionally, commercial and small businesses could take advantage of the physical properties of gelled propellants because of the much simpler, safer, and less costly issues associated with handling and transportation. The small business could commercialize this topic by offering testing services to either NASA or private liquid propulsion companies. DoD is interested in gel propulsion because of thrust management advantages and/or increased safety of gelled propellants. The small business could offer services to both government organizations and liquid propulsion companies. Universities could take advantage of this capability in applying for academic grants.

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KEYWORDS: fuel gel, oxidizer gel, monomethyl hydrazine, inhibited red fuming nitric acid, physical properties, ignition, hypergolic reactions, chemical kinetics.

A06-T002 TITLE: Modeling Software and Tools for Reliability Engineering of Micro/Nano-Device Systems and Components

TECHNOLOGY AREAS: Information Systems, Electronics

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 3.5.b.(7) of the solicitation.

OBJECTIVE: To identify, develop and integrate computational methods for scalable computing that seamlessly couple various length scales for use in the design and analysis of military systems that exhibit stability and reliability under thermal and shock loading. Improved modeling of important mechanisms will be through small and large scale coupled simulations involving mathematically consistent algorithmic and software coupling between the scales. The modeling tools to be developed are critical for improvements in design and development practices of new micro/nano-devices, multi-function sensors, and materials whose primal functions are to operate under battlefield environments.

DESCRIPTION: The mission of Army science and technology is to accelerate and foster maturation of technology that will enable Future Force capabilities to become smaller, lighter, more lethal, more survivable, multi-functional, and autonomous. To address some of the relevant technology areas, including sensors, materials, systems, devices and components, Army Science and Technology (S&T) initiatives must exploit revolutionary new concepts and engineering design procedures through both modeling and experimentation. Recent developments in nanotechnologies demand that the computational engineering of nanosystems be considered from nano/micro scale building blocks in a way that would complement and enhance new device engineering techniques. The ability to translate these advances into engineering designs for new and complex multi-functional military systems has been a weakness for modelers due to the multitude of scientific and computational obstacles that must be overcome. Numerical methods for engineering design have seen a long history of success for problems associated with legacy systems. However, the emergence of nano/micro-technologies presents significant challenges because of the complex issues that exist in intermediate scales where traditional modeling paradigms do not readily apply. For example, the microstructure of materials and grain boundaries has a powerful influence on a variety of material properties, namely, mechanical strength, electrical conductivity, magnetic properties, toughness, etc. Dopants, voids, or general crystalline/polycrystalline/amorphous defects can migrate or evolve so as to deteriorate or enhance engineering properties. Recently, a number of multi-scale computational approaches were developed that couple molecular dynamics with finite elements. Some of the prominent ones are quasicontinuum [1], handshaking [2], bridging domain method [3], and homogenization [4]. These methods are known to be effective for certain classes of applications. But these and other types of "enriched" finite element methods have advantages and disadvantages for multi-scale simulations and are generally inadequate for simulating systems subject to hostile military environments where prominent thermophysical and shock effects occur. Often the only recourse in the absence of multiscale simulation tools in electronics and other related multi-disciplinary areas, such as semiconductor-based

chem/bio detection device designs, is through brute force simulations using stand alone molecular dynamics (MD) codes that are computationally expensive and time consuming. In most instances, multiscale simulations and modeling approaches would ameliorate or facilitate costly simulations and cumbersome design testing. Hence, development of consistent and unified complex mathematical models for bridging the scales and computational frameworks are needed to address multi-scale / multi disciplinary applications. Moreover, general software tools that are portable and scalable are needed to make these developments useful. These unified mathematical models should provide improved understanding between interacting scales and possibly eliminate dependence on heuristics such as finite element meshing restrictions and material approximations. The connection to high performance computing would also alleviate the size restrictions of the models and enable considerations of true system-level scales. There is an urgent need for the development of general purpose scalable software incorporating recent advances in nanomechanics, mathematical algorithms involving different higher order discretization techniques, and multiscale physical laws. This software is expected to become the computational engine in the advanced survivability and lethality analyses of military structures that expose sensors and devices to significant and potentially catastrophic thermal and shock environments.

PHASE I: This portion of the effort will consist of identifying and reviewing seamless, robust, and mathematically consistent multi-scale algorithms currently in existence. The emphasis will be on the broad goal for simulating nonequilibrium thermal and shock physics at meso and microstructural scales where dominant physical mechanisms that govern reliability are beyond the reach of either molecular mechanics or unstructured finite element methods alone. In fact, new modeling methods that replace traditional finite element methods are welcome. Modeling of ambient conditions for either manufacturing (material processing) or in-situ warfighting (post-processed) scenarios are also welcome. This will be followed by identifying necessary computational environments and scalable software approaches for implementing the algorithms which can address typical large-deformation above-room-temperature type military applications – moving towards Multi-scale Applications through High Performance Computers. Preference will be in identifying methodologies and techniques that are mutually compatible for direct numerical implementation with minimal new algorithm development.

PHASE II: Using the results from Phase I, the effort will be to build a robust scalable software and interface to handle a wide variety of Army applications. Technical and user documentation will be developed at this time. Emphasis will be on coupled thermo-electro-mechanical simulations of devices in the submicron regime subjected to dynamic and transient loads. The developed simulation tools will be used to both enhance current designs and establish engineering design rules-of-thumb for electrical performance of complex devices under the aforementioned harsh environmental conditions.

PHASE III DUAL USE APPLICATIONS:

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- 1) E. B. Tadmor, R. Phillips and M. Ortiz, "Hierarchical modeling in the mechanics of materials," *Int. J. Solids Struct.*, 37 (2000) 379—389.
- 2) F. Abraham, J. Broughton, N. Bernstein, E. Kaxiras, Spanning the continuum to quantum length scales in a dynamic simulation of brittle fracture, *Europhys. Lett.* 44 (1998) 783–787.
- 3) S. P. Xiao and T. Belytschko, "A bridging domain method for coupling continua with molecular dynamics," *Comput. Methods Appl. Mech. Engrg.*, 193 (2004) 1645—1669.
- 4) P. W. Chung and R. R. Namburu, "On a formulation for a multiscale atomistic-continuum homogenization method," *Int. J. Solids Structures*, 40 (2003) 2563—2588.

KEYWORDS: numerical methods, computational sciences, multiscale modeling, electronics, reliability, thermophysics

A06-T003 TITLE: Bulk Nitride, Exchange-Coupled Magnet

TECHNOLOGY AREAS: Materials/Processes

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foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: The goal of the program is to identify processing approaches that are amenable to the production of a bulk nitride magnets and demonstrate the commercial viability of preparing nitride-based exchange-coupled permanent magnets.

DESCRIPTION: In the early 1990's several nitrogen-based compounds were identified that displayed outstanding magnetic properties. Unfortunately, processing limitations thwarted commercialization. In particular, $\text{Sm}_2\text{Fe}_{17}\text{N}_x$ was identified as a hard magnet with potential for providing outstanding energy product values at temperatures in excess of 300 C(1,2). Unfortunately, it is unstable at conventional powder sintering temperatures making standard high-temperature compaction and annealing treatments impossible. Likewise, alpha double prime- Fe_{16}N_2 was found to have record saturation magnetizations (estimated to be around 300 emu/gm), but its synthesis involved a peritectic reaction to a metastable phase. To date, only mixtures containing a minority concentration of the high moment phase have been formed, either by quenching and tempering of the nitrogen austenite phase (3) or reactive deposition of iron in a nitrogen atmosphere (4,5). Innovative, new concepts for preparing these particular nitride powders are being sought. In addition, it is desired that methods be explored for combining these into a composite, exchange-coupled (or "spring") magnet (6,7). If a very fine dispersion of the alpha double prime Fe_{16}N_2 phase within an aligned $\text{Sm}_2\text{Fe}_{17}\text{N}_x$ matrix can be obtained then it should be possible to prepare exchange coupled magnets with record energy product values. This would have direct application to the production of lighter, more compact motor/generator systems for use in more-electric vehicles and robotic systems.

PHASE I: Investigate and demonstrate innovative approaches for the powder production of high-performance, nitrogen-based magnets of $\text{Sm}_2\text{Fe}_{17}\text{N}_x$ and alpha double prime Fe_{16}N_2 . Approaches for combining these two phases to produce an isotropic exchange-coupled magnet should be explored in Phase 1. The goal should be to demonstrate overall feasibility for manufacturing nitrided magnets.

PHASE II: The small business should implement the processing innovations identified in Phase 1. This should include the production and testing of prototype magnets. Phase 2 effort should increase the focus on the processing of anisotropic exchange-coupled magnets. Optimization of the various processes should be completed, which should include exploring the major cost and reliability issues associated with the innovation in the context of commercial viability.

PHASE III DUAL USE APPLICATIONS: New nitrogen-based compounds offer very attractive hard ($\text{Sm}_2\text{Fe}_{17}\text{N}_x$) and soft (alpha double prime- Fe_{16}N_2) magnetic properties. These magnets could potentially displace a large fraction of materials currently being used in compact electric motors, magnetic recording heads, power generation equipment/ transformers, and high-temperature magnetic bearings. Each of these areas represent major markets that could be impacted. An optimized nanostructured composite that mixed the two phases could lead to an exchange-coupled magnet that would significantly out perform any permanent magnet currently on the market. This research is intended to provide the processing breakthroughs and feasibility demonstration that facilitates the commercial development of these new classes of high performance permanent and soft magnets.

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- 1) J.M.D. Coey, et al, Proceedings of 35th MMM Conf., FA-02 (1990)
- 2) J.K.Stalick, et al, Mater. Lett. 12, 93 (1991)
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- 4) T.K. Kim and M. Takahashi, Appl. Phy. Ltr., 20, 492 (1972)
- 5) M. Komuro, Y. Kozono, M. Hanazono and Y. Sugita, J. Appl. Phys. 67, 5126 (1990)
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KEYWORDS: processing nitrogen-based magnets, permanent and soft nitrided magnets, exchange-coupled or spring magnets

TECHNOLOGY AREAS: Chemical/Bio Defense

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OBJECTIVE: Develop a safe, portable, economical microreactor system capable of synthesizing either liquid or vaporous hydrogen peroxide for use at Army base and battlefield installations from reactants available in the field (e.g. water, air, salt). If liquid is produced, the system should serve as a unit operation upstream of an evaporation unit that can feed into the interior of any contaminated building or military vehicle for the purpose of neutralizing chemical and biological agents.

DESCRIPTION: The Army has developed partnered technology that utilizes vaporous hydrogen peroxide (VHP) as a means of treating enclosed areas (buildings, aircraft, tanks) that have been contaminated by pathogens such as anthrax or chemical agents such as mustard gas. The attractiveness of VHP for decontamination stems from its versatility, permeability, relative safety, and its effectiveness without damaging sensitive equipment. Rather than transporting and storing large volumes of hydrogen peroxide solution to remote areas, it would be more advantageous to deploy a portable microreactor system for synthesizing hydrogen peroxide on demand.

While the traditional method of synthesizing hydrogen peroxide involves the use of organic solvents and alkylated anthraquinones, recent reports have indicated that synthesis can be achieved directly from hydrogen and oxygen or, more compellingly, from the electrolysis of water. While yields and resulting hydrogen peroxide concentrations have been limited by these new methods, it is thought that improvements in reactor performance can be realized by the use of microreactors. Microreaction technology has been developed as a novel means of intensifying reactor systems. Compared to traditional reactors, micro-fabricated reactors exhibit considerably higher area to volume ratios resulting in more efficient heat and mass transfer capabilities, better control of energy distribution, and greater avoidance of side reactions. Increases in throughput are achieved by designs that incorporate multiple reactors run in parallel ("numbering up"). Microreactors can also be readily integrated with sensors, control systems and other unit operations while their miniaturization makes them attractive for Army field use. This effort calls for the design and testing of a high throughput microreactor system that can maximize yield of hydrogen peroxide and is suitable for decontamination purposes by the Army.

PHASE I: Design, develop, fabricate and test a safe, economical microreactor prototype that is capable of generating either liquid or vaporous hydrogen peroxide from non-hazardous reactants. The design of the unit with regard to parameters such as reaction scheme, flow scheme, physical dimensions, and catalyst selection should result in an optimal yield of product while minimizing side reactions. The reactor should produce hydrogen peroxide either as an aqueous solution at a concentration of 35% (w/v) or as a vapor at a concentration of 250-500 ppm. By the end of this phase, a plan that specifies the cost and size of the unit for large-scale production should be developed.

PHASE II: A numbered up unit capable of increased throughput should be designed and fabricated. A scaled-up unit that produces liquid should be capable of generating 1-50 lb of liquid hydrogen peroxide per day. If vapor is produced, throughput should be sufficient to decontaminate an interior space of 1000-5000 cu ft. The unit should be easily operable by individuals fitted with requisite protective gear and capable of feeding a downstream evaporator. The design should include specifications for pumps, fittings, materials selection, controls (pressure, temperature, flow), chemical sensors and adequate flow distribution. The reactor should be compact, economical, durable, and functional in extreme temperature and environmental conditions.

PHASE III DUAL USE APPLICATIONS: This unit will have utility as a quick efficient means of generating hydrogen peroxide for both remote military and civilian installations where storage of the liquid is impractical. Since this reactor system will be compact and economical, many units can be fabricated and deployed. This compact and rugged device will improve the ability of the Army to neutralize chemical and biological threats by simplifying the logistics of decontamination and making the procedure more economical.

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- 2) D.L. Dutt, A.L. Turetsky, M. Brickhouse, J.W. Pfarr, I.F. McVey, S.L. Meilander, A.J. Janick, S.L. Schulte, and A.W. Dallmier, Effectiveness of Vaporous Hydrogen Peroxide for the Decontamination of Representative Military Materials. 24th Army Science Conference Proceedings, 2004.
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KEYWORDS: decontamination, hydrogen peroxide, anthrax, microreactor

A06-T005 TITLE: Low Power Retroreflectors for Optical Communications

TECHNOLOGY AREAS: Information Systems, Sensors

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OBJECTIVE: To develop a compact, portable, low power, light weight, low cost, modulated retroreflector device for use in high-bandwidth, stealthy, free-space optical communications links. The proposed research is aimed at developing the underlying principle of operation and associated hardware needed to create a reliable optical distributed communications network comprising optical modulated retroreflectors.

DESCRIPTION: As battlefield systems become more reliant on sensor networks to provide up-to-date information, there emerges a need for low-power, compact, and stealthy communication capability between the active querying node and one or more sensor nodes. Such communication is necessary for applications that include identify-friend-or-foe interrogation, sniper identification and location, ad-hoc mesh networks, air-to-ground links, and unmanned autonomous vehicle monitoring. An attractive architecture for many of these applications is one that makes use of sensor nodes with modulated retroreflectors. A major benefit of this proposed architecture is that it requires no beam generating capacity or active beam steering by passive nodes. A steered beam from an active node would provide illumination for passive nodes, the passive nodes can then modulate the signal before reflecting it back to the active interrogating node. Such a system would provide line-of-sight communications for sensors having limited energy capacity and/or limited size.

Two basic architectures have emerged for modulated retroreflectors: those that use a modulated shutter in front of a passive optical retroreflector, and those that use a modulating reflective surface as one facet of the retroreflector itself. In the former architecture, modulation is achieved by reducing the intensity of light entering and leaving the retroreflector. In the latter, modulation is achieved by spoiling the retroreflective characteristics of the corner cube by tilting or reshaping one of its facets.

The bandwidth of the devices depends entirely on the physical means of the modulation employed.

The most common form of shutter modulator is the Multiple Quantum Well (MQW) device. MQWs are exceptionally fast, solid-state components, capable of switching at frequencies up to many hundreds of megahertz. Because their construction requires precisely controlled deposition of up to a hundred layers of thin films, MQWs are inherently expensive components. They cost many thousands of dollars per modulator, but are well-suited for mission-critical tasks such as UAV downlinks. A limitation of this type of modulator is the relatively small contrast

achieved by the shutter. With only about a factor of three difference in absorption separating the on and off states, the range of such modulated retroreflectors is challenged by signal-to-noise considerations.

Modulated retroreflectors based on MicroElectroMechanical Systems (MEMS) technology such as Deformable Mirrors (DM) offer an attractive alternative. For such devices, the modulator could occupy one facet of a corner retroreflector. The modulator would have the characteristic that it could be made to act as a normal plane mirror, maximizing the amount of light that is retroreflected, or it could be made to act as a non-plane or non-normal mirror, reducing the amount of light that is retroreflected. The surface contour of the mirror would be altered to achieve these two different states. MEMS devices hold the promise of being inexpensive to produce, they can be made with optical quality surfaces, and they can be actuated with sufficient speed to achieve data rates of up to a megahertz. Further, electrostatic actuation offers an inherently low power means to modulate a retroreflector, and the MEMS device substrate (silicon) offers an optically flat and smooth surface that can be mated with commercial off-the shelf glass retroreflectors.

The goal of this effort is to make possible some of the benefits offered by free-space optical communications links by employing miniature photoreflexor modulating devices. The result will be the creation of a new breed of compact, portable, low power, light weight, low cost devices for use in stealthy military communications applications.

PHASE I: This phase will determine, through the appropriate system level modeling, analysis, and laboratory testing, the most promising architectures for low-powered free-space modulated optical retroreflector technology for Army applications. The device performance will be evaluated based on the following metrics: bandwidth (>100kHz), size (<50cm³), cost (<\$50), range (up to 1km), ease of fabrication and maintainability, durability, weight, endurance, and reliability.

PHASE II: Demonstration: design, build, and test a prototype comprising no less than three retroreflector devices from the device determined from Phase I. The contractor will be responsible for developing and submitting a test plan for approval by the Army. In the interests of reducing development and test costs, a surrogate laser (i.e. illuminator) may be used for test purposes to evaluate the system's performance.

PHASE III DUAL USE APPLICATIONS: Design, build, and test a demonstration system for a group of no less than seven networked devices. The system will be tested under a variety of environmental conditions to evaluate its performance and reliability. Successful commercialization will include incorporating this technology into a demonstration based upon a currently fielded system, such as identify-friend-or-foe for ground forces. Future commercial applications seen for this technology are in aiding search and rescue operations in remote areas such as in mountainous terrain and at sea, sniper identification and location, ad-hoc mesh networks, air-to-ground links, and unmanned autonomous vehicle monitoring.

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- 4) Haas, S.M., Shapiro, J.H., & Tarokh, V., 2001. "Space-time codes for wireless optical channels," in Proceedings of the 2001 IEEE International Symposium on Information Theory, June 24-29, 2001, Washington, DC.

KEYWORDS: optical communications, retroreflectors

A06-T006 TITLE: Orthogonal Spectroscopic Technologies for the Detection of Hazardous Substances

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: To develop innovative technologies based on multiple spectroscopic sensing techniques for the detection and identification of a wide range of hazardous materials at close-contact and standoff distances. Laser Induced Breakdown Spectroscopy (LIBS) has recently been successfully transitioned to field applications in both close-contact and standoff modes and is especially attractive since it provides a complete chemical composition inventory of a wide range of hazardous materials. However, in complex real-world sensing applications, improved probability of detection (Pd) and low false alarm rate (FAR) are desired, which are unlikely to be accomplished without the additional use of other, complementary spectroscopic techniques. Innovative approaches are sought to combine LIBS with other spectroscopic sensing techniques on the same platform in a manner that minimally increases the size, weight, and cost of the detector package and that is sufficiently rugged for field applications.

DESCRIPTION: For a number of years it has been generally understood and appreciated that significant improvements in the detection and identification of trace amounts of hazardous materials at the desired levels of low false alarm rates and sensitivity will require the near-simultaneous use of multiple 'orthogonal' sensor techniques that provide complementary information that can be used for material detection and classification. In spite of this awareness, few actual systems have been developed that combine multiple techniques in a practical and field-worthy way. LIBS is the technique of choice as the anchor technology due to its unusual versatility, both with regards to its applicability, in principle, to detect all chemical elements down to the trace level, as well as to its versatility for both close-contact and standoff detection. The literature has examples of early work on combining LIBS with Raman (ref. 1,2), laser induced fluorescence (ref. 3), and reflectance (ref. 4). Although clearly promising, the combination of LIBS with other detectors has not yet been realized or optimized for practical sensing applications in the field.

PHASE I: Develop and breadboard a LIBS-based system that combines at least one other spectroscopic detection technique. Laboratory measurements and demonstration of combined performance related to the detection of trace amounts of hazardous materials (e.g. DNT which is easily obtainable) is necessary. This effort will also include a design for a full prototype to be constructed in Phase II.

PHASE II: Construction of prototype 'orthogonal' sensor system (both close-contact and standoff) that combine LIBS with another technology that is sufficiently rugged for field testing. The prototype will be tested under field conditions delivered to ARL. Innovative approaches that lead to reduced size, weight, and cost are particularly encouraged. Improvements in discrimination potential (increased Pd and reduced FAR) over stand-alone LIBS systems will need to be demonstrated. Close interaction with the ARL standoff and close-contact LIBS developmental projects will be encouraged.

PHASE III DUAL USE APPLICATIONS: Development of a commercializable/marketable multi-technology (orthogonal) system for trace hazards detection. Potential Military applications include the detection and discrimination of different hazardous materials on the battlefield. Multiple civilian applications are envisioned both in the environmental arena and in industrial process monitoring. With proven superior performance over LIBS (or other optical stand-alone sensors), a combined unit will be very attractive to numerous customers.

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KEYWORDS: LIBS, spectroscopic sensors, hazardous material detection

A06-T007 **TITLE:** Multifunctional Nanoparticles for Tracking of Materiel

TECHNOLOGY AREAS: Materials/Processes, 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 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop a multifunctional spectroscopic tag that is visible only during interrogation. The interrogation will be performed using either infrared (IR) or ultraviolet (UV) irradiation, depending on the user's needs. Tagging will be accomplished by the physical adsorption of multifunctional nanoparticles containing chromophores that are capable of producing IR and UV signatures on surfaces, including fabrics. Attachment of the tags will occur by spray or similar application. The tag will be used to identify and monitor materiel flow during transport. Interested parties are encouraged to contact the topic chief.

DESCRIPTION: The ability to tag and track equipment and other supplies is an important logistical need. An effective tagging strategy requires that materials can be easily differentiated. The tag must be easily applied and possess suitable stability such that it lasts for days under ambient conditions, including extreme heat, cold and sunlight. The tag should have excellent adhesion to materials, including fabrics so it remains attached to the surface during transport and after contact with water; it should be nontoxic. Visible detection of the tag should require a simple device, such as a hand-held UV lamp or an IR detector, allowing detection under daylight and nighttime conditions. This topic will exploit advances in functional nanoparticle synthesis (references 1-5) to prepare systems that contain functionality that is observable using IR and UV detection.

PHASE I: Research will focus on determining optimum particle composition and size and the requisite chromophore/nanoparticle coupling chemistry for attachment of suitable chromophores for both IR and UV detection. Chromophores and materials that obscure, enhance, or significantly change an IR signature (references 6-8) and fluoresce at variable wavelengths (i.e., 254nm, 365nm) will be identified and evaluated. Efficacy of the IR tags will be determined at wavelengths of interest to the Army. Phase I will primarily involve screening experiments designed to provide proof of concept demonstration of this technique.

PHASE II: Chromophore stability will be determined under a variety of extreme conditions, including light, temperature, humidity, water, and shock. Particle dispersive properties will be determined along with characterization of physisorption to materials. Dispersion properties of the particles as well as stability of the IR/UV signature will be determined for conditions typically encountered by DoD. Chromophore concentration within the particles will be set during these tests. Conditions that deactivate, inhibit, and remove the chromophore from the surface or make it unusable will be determined.

PHASE III DUAL USE APPLICATIONS: This technology currently does not exist and would be of great interest to commercial shippers. Phase III will focus on economical scale-up of promising nanoparticles.

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- 2) Zhang, Z.; Han, M., "One-Step Preparation of Size-Selected and Well-Dispersed Silver Nanocrystals in Polyacrylonitrile by Simultaneous Reduction and Polymerization," *J. Mater. Chem.* 2003, 13, 641-643.
- 3) Thomas, K.G.; Kamat, P.V., "Chromophore-Functionalized Gold Nanoparticles," *Acc. Chem. Res.* 2003, 36, 888-898.
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KEYWORDS: tagging, tracking, spectroscopic, infrared, ultraviolet

A06-T008 TITLE: Mobile Ad Hoc Communications Network Simulation Acceleration Using Parallel Processing Hardware

TECHNOLOGY AREAS: Information Systems

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 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this STTR is to develop an integrated hardware-software solution for performance prediction and analysis of tactical ad hoc networks comprised of hundreds or even thousands of nodes.

DESCRIPTION: One of the innovations upon which the Army's Future Combat System will be built is the Tactical Mobile Ad hoc Communications Network (TMACN). TMACN technology is important because it will provide the backbone for exchange and sharing of information from sensors, manned and unmanned vehicles and systems, and dismounted soldiers. Some of the unique features that distinguish TMACNs from traditional wireless networks are their mobility; they must be self contained and have the ability to move to support forces as engagements change, their adaptability; they must be able to reconfigure themselves in real-time as new nodes are added and others are lost, and their size; they may be on the order of hundreds or even thousands of nodes. The uniqueness associated with TMACNs gives rise to several complexities that limits a satisfactory solution for performance prediction; theories required to predict their performance have yet to be developed, and adequate hardware to test them is still years away. The focus of this effort is to develop a performance prediction solution for TMACNs based on simulation.

Computation time currently limits the usefulness of high fidelity software-only based simulations for TMACN performance prediction. For each link, simulations must have an accurate physical model to assess the effect of each transmitter. Current state of the art makes the problem tractable in one of two ways; by using an overly simplistic model of the physical layer that results in a highly inaccurate prediction model, or reducing the number of nodes to an untenable level. One way to maintain the fidelity of the simulation without increasing the compute time is to use parallel processing through dedicated distributed hardware. A recent development in chip design [1], [2], both in individual processing unit design and interconnections between processors on the chips, indicates that a scalable near real-time or even possibly faster than real time simulator may be possible utilizing this approach. This effort seeks to capitalize on this recent innovation by calling for the development of an integrated hardware-software solution, one based on this new chip technology that would allow for accurate performance prediction of TMACNs comprised of hundreds or even thousands of nodes.

PHASE I: Research, development, and trade-off analysis of hardware and software architectures for the parallel processing MANET simulator. This should include multiple processors per chip technology in order to facilitate transfer of information. On and off chip communications should be considered, as well as processor architecture. Present the analysis and propose an architecture for the simulator in a report. In particular, the scalability analysis should be included in the report, since this is critical to the program. The report will also include a summary of potential commercial applications and the projected benefits from the use of this technology that could form the basis of commercial business opportunities. Build a prototype small network simulator (~10 nodes), if possible.

PHASE II: Further develop the design proposed in Phase I. Use the results to implement a simulator of at least 200 nodes. Demonstrate the simulator with a realistic tactical scenario.

PHASE III DUAL USE APPLICATIONS: Refine the software and interfaces to be useable DoD applications. Make improvements to increase the number of nodes to be at least 1000. Suggested non-DoD applications include simulation of wired, wireless and combined wired/wireless networks.

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KEYWORDS: mobile ad-hoc networks, simulation, parallel processing

A06-T009 TITLE: Performance Map for Low-Cost Titanium Armor

TECHNOLOGY AREAS: Ground/Sea Vehicles, 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 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop a design map for titanium material properties, spanning the range of compositions and microstructures achievable with commercial extraction and processing technology, to guide the design and production of low-cost titanium armor and protective structures.

DESCRIPTION: The increasingly hostile and uncertain environment of the modern battlefield creates an enormous need for advanced materials to protect both individual war fighters and advanced battle systems. While new opportunities continue to emerge in advanced composite armor designs, steel continues to have a significant use in armor and structural materials applications due to its inherent low cost, durability on the battlefield, ease of processing, and robust characterization. Such long-standing advantages have enabled an extraordinary investment of time and resources for the maturation of steel metallurgy. However, with the recent demand for increasingly lighter armor and protective structure solutions to meet mission requirements, the advantages of titanium alloys (i.e., superb specific strengths, low thermal expansions, and high environmental tolerance) have increased dramatically. Due to these superior properties alone, the titanium market is expected to continue its growth into a wide range of commercial and defense sectors; however, recent breakthroughs are poised (with DoD support) to bring about an unprecedented (i.e., greater than 50%) drop in titanium extraction costs that would dramatically broaden the use of titanium alloys.

This solicitation seeks the development of a robust titanium alloy performance map to enable armor and protective structure designers to rapidly identify the optimal combination of composition and microstructure to meet the rigorous performance requirements inherent to these applications. While the inherent anisotropy of titanium greatly complicates the range of microstructures that can be synthesized, this very anisotropy also provides an enormous range of achievable material properties with extraordinary potential; however, a long-term sustained investment in titanium metallurgy is not possible.

Rather, and based upon recent advances in materials design theory, the opportunity now exists to create detailed microstructure-composition-property maps representing the effect of relevant compositional and microstructural variations on the critical materials properties for armor and protective structures. Specifically, a successful effort is expected to utilize a mathematical framework capable of representing microstructure and composition as design variables based on a reduced set of pertinent physics and mechanics. Such mathematical representations (many of which have only recently been developed) offer tremendous potential for the future of materials engineering: optimizing material microstructures to meet specified design requirements. From this basis, materials processing targets could be readily identified to guide the rapid introduction of optimized titanium alloys into military protective applications. It is expected that a successful effort will provide a robust set of material properties maps for titanium alloys incorporating: composition, microstructure, method of processing, cost, and materials theory in order to affect all aspects of armor and protective structure design.

PHASE I: Develop the computational framework necessary to represent the range of titanium material properties, compositions and microstructures achievable with commercial and anticipated extraction and processing technology.

Demonstrate this capability by providing a precise property map for the specific strength of titanium alloys incorporating composition, microstructure, and method of processing. Develop roadmap for expanding the titanium alloy performance map to a wide range of property closures.

PHASE II: Develop a robust and precise performance map of titanium material properties relevant to armor and protective structure design, with additional guidance from armor and protective structure design experts. Validate regions of the full performance map with materials properties ranging from commercial grade alloys to scrap titanium. Demonstrate utility of full performance map by designing sample virtual materials and processing requirements optimized for: a) protective structural performance over all possible titanium compositions, microstructures, methods of processing and costs and b) protective structural performance over a reduced set of least expensive titanium alloys and processing methods.

PHASE III DUAL USE APPLICATIONS: A detailed performance map of titanium material properties is expected to be readily commercializeable to the titanium processing industry, which would impact a broad range of military and civilian protective and structural applications where advanced properties are necessary, including soldier and civilian body armor, as well as vehicle, automotive, and infrastructure structures and protective materials.

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KEYWORDS: titanium armor structure design

A06-T010 TITLE: 2-D 2-Color Laser Spot Array Generation for Quantum Computing Applications

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Design and development of an innovative optical device to generate two-dimensional arrays of two-color laser spots to address, operate, and read-out qubits for scalable quantum computing.

DESCRIPTION: Two-dimensional arrays of qubits are anticipated to be a central feature of scalable quantum computing architectures. Physical embodiments of these qubit arrays could be trapped neutral atoms, trapped ions, or quantum dots. Typically, qubits are manipulated (gate operations) and measured (read-out) using optical (lasers) means. Innovative optical devices and technology and creative approaches that produce a 2-D array of rapidly addressable diffraction-limited laser spots are an enabling technology and are sought for quantum computing. Requirements and features of these optical devices are described below for trapped neutral atoms. Similar features are needed for arrays involving quantum dots or trapped ions although geometry and operating colors may vary. References below provide guidance for these applications.

- (a) Two color operation at the same location for two-photon excitation operations. In the case of two photon excitation of Rydberg states the desired wavelengths are 480nm and 780nm.
- (b) High efficiency operation to minimize laser power. Diffraction efficiencies higher than 50% are desired.
- (c) No Doppler shift in the output as this shift will detune transitions. Other methods to compensate for the effects of the Doppler shift can also be considered.
- (d) Frame rates (access time) in the MHz range.
- (e) Scalability to array sizes of 100 X 100 or larger.

Typical atom spacing in a trap is in the range 5-10 μ m.

Commercial off-the-shelf devices fall short or are unable to meet these requirements. Current technology that may provide a foundation for the development sought here includes spatial light modulators, fast steering mirrors, and acousto-optic deflectors. Devices developed here are anticipated to have a broader application involving other 2-D arrays of qubits based on other technology.

PHASE I: A key demonstration of feasibility would be an experiment based on the proposed technology to generate a two-color two-dimensional array of laser spots. The Phase I study should also complete design of a device to meet requirements stated above and estimate device performance. Adaptability of the design to variations of requirements for different quantum computing technologies should be highlighted.

PHASE II: A prototype device to address a 10X10 array of qubits will be built and tested. Requirements and testing should be done in coordination with an experimental group developing the appropriate quantum computing technology.

PHASE III DUAL USE APPLICATIONS: The technology developed here has application to a broad range of quantum computing technologies involving arrays of qubits, such as quantum dot arrays. In addition to critical national security applications, quantum computing is anticipated to have an impact on commercial applications involving hard computational problems such as planning and scheduling. The technology developed here is also anticipated to have wide application to DOD and commercial applications involving dense addressable arrays such as nanoscale sensor arrays, optical switches, imaging, and displays.

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KEYWORDS: laser spot array, quantum computing, acousto-optic deflectors, spatial light modulators, beam steering

A06-T011 TITLE: Software for Generating Geometrically and Topologically Accurate Urban Terrain Models Using Implicit Methods

TECHNOLOGY AREAS: Information Systems

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 3.5.b.(7) of the solicitation.

OBJECTIVE: Design and develop software for obtaining models of urban terrain from point-cloud data using implicit representation

DESCRIPTION: Currently, the terrain models in most widespread use consist of surfaces represented explicitly as planar triangular facets connected in a continuous manner with each other (triangular irregular networks or TINs). Generally, these models are “terrain skins,” that is, representations of height as a univalent function of two independent lateral variables (such as latitude and longitude). Objects with multivalent height and non-genus-0 topology are often added onto these terrain skins to make the terrain model approximate reality closer. However, for urban terrain, the number of such objects and the corresponding computational burden are huge. Raw data that corresponds to objects with multivalent height and non-genus-0 topology (bridges, overhangs, underpasses, buildings, subways, etc.) is becoming widely available. Given this situation, it is important to develop methods that generate geometrically and topologically accurate terrain models from raw point-cloud data in a computationally efficient manner. The commonly used “explicit” methods (methods that provide an explicit representation of the surface(s)) have not yet “topped out” and may be able to do this. Implicit methods, that is, methods based on level-set technology [1,2] are also a candidate for doing this. Implicit methods have successfully been used for individual geometric objects, including complicated objects, and for dynamic simulation of complicated physical situations (for example, water flow in complicated geometries). However, implicit methods have not been thoroughly investigated

for representation of intricate urban landscapes. Computational complexity is a potential limitation of implicit methods, but implicit methods have some clear advantages, including 1) the ease of performing unions and intersection operations with simple operations applied to the field function, 2) the ability to obtain multi-resolution models with simple sampling of the field function and 3) the ease of incorporating corners and sharp features in the surface model without having to pre-describe discontinuities or other properties of the field function.

PHASE I: Carry out a design study that will determine the advantages and limitations of adaptive, implicit urban-terrain models constructed from point-cloud data. The field function of the implicit model should be a piecewise polynomial defined over a volume-cellular decomposition of the bounding domain of the point cloud. The design study should include 1) selection and determination of the method of representation of the basis functions for the piecewise defined field function, 2) determination of the method of imposing global continuity constraints across cell boundaries, 3) selection of the method of adaptively subdividing the domain, 4) selection of metrics for fitting point cloud data and algorithm selection for computing optimal approximations, 5) selection/collection of a data sets for validation, 6) determination of methods for extracting and rendering of surface fitting model from the implicit model and 7) a plan for the modules and a flowchart for a software to implement the model.

PHASE II: Develop software for adaptively computing implicit models for urban terrain. This software should be compatible with or plug in to one or more widely used software systems for terrain modeling. Compare the implicit form of representation to traditional explicit methods on the basis of: 1) storage requirements, 2) ease of computing multiresolution models and 3) efficiency for calculation of line of sight regions. Carry out validation and verification of this software. Identify limitations of the software and determine whether these limitations are due to fundamental technical barriers. Carry out a demonstration of the software.

PHASE III DUAL USE APPLICATIONS: The system produced by this effort will support a broad range of military and civilian applications where mathematical modeling of urban terrain is required. Military applications include modeling of urban terrain warfare environments for training, mission planning and rehearsal, simulation and tactical planning. Civil applications include urban planning, emergency and response management, support of homeland security and counter-terrorism tactics planning, and crime investigation.

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- 1) S.J. Osher and R. Fedkiw. Level-set methods: an overview and some recent results, J. Comput. Physics 169 (2001), 463-502.
- 2) H.-K. Zhao, S. Osher, R. Fedkiw, Fast Surface Reconstruction Using the Level Set Method, 1st IEEE Workshop on Variational and Level Set Methods, in conjunction with the 8th International Conference on Computer Vision (ICCV), Vancouver, Canada, 2001, pp. 194-202.

KEYWORDS: computational geometry, implicit models, terrain modeling, topology, urban modeling

A06-T012 TITLE: Nanoscale Antennas

TECHNOLOGY AREAS: Electronics

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 3.5.b.(7) of the solicitation.

OBJECTIVE: To design, build and demonstrate a new class of antennas aimed at coupling RF signals into and out of nanoscale devices and sensors. Applications include radio-frequency identification (RFID), stealth materials based on nanoscale electromagnetic components, and interconnect technologies for nanoelectronic device and integrated systems.

DESCRIPTION: Until recently the domain of nanoelectronics devices belonged to the domain of wired electronics. Due to their small device size, coupling of nanometer scale devices to microwaves has been negligible, because the microwave wavelength (centimeters) is much larger than the device size. A recent series of breakthrough discoveries

in materials synthesis [1-10] have resulted in the ability to synthesize carbon nanotubes as long as the wavelength of microwaves and RF waves, of order several mm to several cm in length. These systems may now allow, for the first time, the possibility of wirelessly coupling microwaves from free space into nanoscale electronic devices and sensors [11]. This opens the door to some promising applications in RFID, wireless biosensors, and microwave materials such as EM shielding and stealth materials.

For example, since biological activity occurs extensively on the nanoscale, a very exciting opportunity is now potentially enabled by the use of mm long carbon nanotube antennas: Wireless connections to nanoscale sensors of biological and chemical activity that are minimally invasive and extremely low cost. This would allow for new levels and aspects of biological and chemical warfare threat detection. RFID sensors based on nanotube antennas could also be envisioned which are extremely cheap to manufacture and could be incorporated onto almost any item needed tracking of very small size, down to a few cubic millimeters. While the military applications are clear (tracking of munitions, foodstuffs, etc.), dual-use applications are equally ubiquitous. EM shielding and stealth materials are also enabled by this new materials system, if it can be manufactured in bulk. EM shielding is based on conductive polymers. With the new extremely high aspect ratio nanotubes, which have a 3d conductivity greater than copper at least up to 10 GHz [12], the prospects of low-cost, flexible, polarization dependent EM shielding and stealth materials are now a real possibility. A final noteworthy application area is in the coupling to ultra-low capacitance nanoscale THz detectors, where fringing capacitance from conventional, lithographically fabricated wiring provides a capacitive short which lowers power coupling and hence detector efficiency. Here again, breakthroughs in the synthesis of ultra-long nanotubes are an enabling technology for their use as antennas in THz detection and transmission systems. Taken collectively these new technologies enabled by recent discoveries can be collectively described as "nanoscale antennas."

PHASE I: Phase 1 of the program should demonstrate proof-of-concept of nanotubes as both receiving and transmitting antennas. This means characterization and demonstration of antenna pattern and efficiency. Demonstrate RFID proof of concept and wireless biosensors proof of concept.

PHASE II: In Phase 2 of the program, manufacturing techniques to enable economical fabrication of nanoscale antennas will be improved upon. For example, techniques to disperse ultra-long antennas in solution and coat them onto other supporting materials will be developed. The supporting materials may be solids or flexible materials.

PHASE III DUAL USE APPLICATIONS: Successful development of this innovative antenna technology will bring new capabilities for integration of nanoscale technologies into a wide range of electronic materials and systems. The technology will produce new materials for enhancing stealth capabilities and producing polarization sensitive electromagnetic shielding of interest to the DoD, and enable high bandwidth wireless data transfer from nanoscale chemical/biological sensor networks and RFID tags of critical interest to the Department of Homeland Security and the commercial logistics sector. The simplicity and low-cost of manufacturing for these systems will lead to numerous other products and widespread applications in the commercial and defense industries.

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KEYWORDS: antenna, radio-frequency identification RFID, nanotechnology

A06-T013 TITLE: Development of a Neural Co-Culture Bioactive Compound Sensor

TECHNOLOGY AREAS: Biomedical, Human Systems

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 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop a bioactive compound sensor device based on a living cell culture that maintains both differentiated association and motor neurons in a 2 chambered communicating system in which both stimulating and recording electrodes arrays can act to provide and measure computer generated virtual effectors to the motor neurons and virtual senses to the association neurons, and in which the association neurons can communicate with the motor neurons via axonal outgrowth and natural synapse formation in the sensing area.

DESCRIPTION: Existing research in cell cultures have succeeded in maintaining differentiated neurons and linking them via embedded contacts to computer driven circuits (e.g. Potter & DeMarse, 2001). These true synaptically communicating neural networks have demonstrated learning and the ability to produce defined and useful output (e.g. Wagenaar et al, 2004, Bakkum et al, 2004). Other research in human volunteers has revealed that superior shooting performance is marked by efficient cortical dynamics and a modulation of the activity between association and motor cortices (e.g. Kerrick et al, 2004). What is missing is the link between an ad hoc self-assembled neural network and the modularly arranged native cortical structure in order to determine the detailed methods by which one type (or module) of cortex modulates the efficiency and function of another module. Behaviorally, this intra-module communication is a critical component of peak performance, but it is uniquely difficult to approach in a quantitative, reductionist manner. A sensor based on a bipartite differentiated neural network would allow for complete environmental control e.g. exposure to external compounds and/or pathogens and would be an important technical advance permitting sensitive measurement of disturbances to the primary mechanisms for meaningful neural signal traffic. Such a sensor device whose active element is the synapse rather than the cells themselves would go beyond gross lethality analysis of a cell type to measurement of cellular network function. Further expansion of this system would permit the comparison of different neural genotypes and biomarkers for enhanced function and expose the basic mechanisms of genomic control in neural networks as well as permitting testing of therapeutic or protective interventions.

PHASE I: 1) Successfully explant and maintain association and motor cortex neurons from any suitable candidate mammal; 2) successfully establish the differentiated cell cultures on electrode arrays demonstrating both recording and stimulating capability; 3) demonstrate axonal communication from the association neurons to the motor neurons; 4) demonstrate a simple computer modulated feedback loop from the motor neurons to the association neurons; 5) demonstrate sensitivity of the neural traffic measures to a single environmental (biochemical) manipulation.

PHASE II: 1) develop a teaching algorithm for the co-cultured system to learn a simple motor sequence; 2) build an actual sensor device and assay a range of biochemical compounds selected or designed to enhance and/or degrade the efficiency of the motor sequence performance by affecting the association cells, the motor cells and specifically the axonal communication between them; 3) confirm the prediction of changed efficiency with a parallel motor task in a model small mammal.

PHASE III DUAL USE APPLICATIONS: This relatively simple cell based sensor system will allow the testing of neuro-active compounds efficiently and simply for their effect both on neural network learning and efficiency. These candidate compounds may range over the needs of combating sleep deprivation, counteracting chemical or biological insult, biochemical imbalances induced by nutritional status, etc. Investigation of genomic expression in these cultures could provide critical clues in diseases and conditions affecting the nervous system. Eventual applications for the screened biomaterials can include both civilian and military arenas in which mental and physical performance must be sustained and protected.

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KEYWORDS: Neurons, sensors, learning, biomodulation, synapse, co-culture, organotypic, brain, robotics.

A06-T014 TITLE: Optimal Design of Compact Fuel Cell Hybrid Power Systems

TECHNOLOGY AREAS: Ground/Sea Vehicles, 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 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop a systems-level computational model and software that enables optimal selection of power-system components and design of a complete compact (soldier portable) fuel cell power system that meets a given user-specified power-profile and energy-use constraint.

DESCRIPTION: The electrical power and energy demands of the future dismounted warrior for communication, computation, sensing, etc. will be mission sensitive, and the power load will be time-varying. Non-steady power demands will best be met by hybrid power systems (1, 2). For example, consider a 20-W base load that is challenged with pulse demands of 50 W. Depending upon duration of the high-power pulse, it may be advantageous to couple the energy converter for the base load (fuel cell) with a supercapacitor (short duration) or battery (longer duration) to support the high-power demands; potentially, combinations of the two may be optimal. A recent National Research Council report (3) discusses the energy needs of the future warrior, and it recommends that smart hybrid power systems be developed, in part based upon a modeling approach. The report states: "One challenge with the modeling approach is to develop code with general rules that can be rapidly adapted by systems engineers to help guide their choices towards compromises that may save power in the overall system. Also, the models need to be able to take into account the behavior of real systems---that is, systems that fade in performance over time or have a range of performance values."

With high-fidelity and realistic component-level models available, academia advances in optimization methods can be utilized to expedite specification, selection, design, and construction of a compact power source for the dismounted warrior. For example, Dougal and co-workers (4) are developing a Virtual Test Bed, with a goal of optimizing the usage of charge storage devices, including fuel cells, batteries, and supercapacitors, for specialized applications. Barton and co-workers (5) have demonstrated how a systems-modeling approach can be formulated to determine optimal electrochemical energy-conversion device and fuel choice for a microfabricated fuel cell power system. Chemistry-based battery models are available for cell design (e.g., 6), and models for fuel cells are being developed by academic, government, and commercial laboratories (e.g., 7).

The computational models at the component level must not only capture with high fidelity the weight, volume, and performance characteristics of the electrochemical subsystems (including fade in performance over time), but weight-volume-performance characteristics must also be accurately modeled for the equally important balance-of-plant components (e.g., pumps, valves, heat/mass exchangers, power electronics, etc...). Ultimately, the model and optimization approach to the design of compact power systems must be verified with experimental data and used in complement with it to fine tune the parameters of the optimization. As the NRC report summarizes, "Ideally, the military should develop and acquire new equipment based on recommendations and considerations gained from power sources modeling, so that the lifetime of the equipment can be maximized."

PHASE I: Define, develop, and verify appropriate-fidelity physics-chemistry based component-level models for a single fuel cell technology (e.g., SOFC or PEM) and the corresponding component-level models for electrochemical devices to meet pulse-power demands (e.g., batteries of varying chemistry and supercapacitors). Define the minimal set of essential physicochemical parameters that describe each component-level model and demonstrate that these models accurately capture experimental results. Demonstrate how these models may be integrated and used within a computational approach of modern optimization theory to determine an optimal compact power system for a given power profile and energy demand, with specified system weight and volume constraints. Develop a plan how the demonstrated approach will be extended in a Phase II effort to envelop a more encompassing optimization in which fuel cell technology is not a priori specified and complete balance-of-plant components are considered.

PHASE II: Develop and implement the approach and code to optimize a compact fuel-cell based hybrid power system for the dismounted soldier subject to a given power profile and energy demand, with weight and volume constraints specified. Coding must be sufficiently flexible and user-friendly to enable incorporation as they become available of new or refined physics-chemistry based component-level models. Validate experimentally the optimization approach and demonstrate how computational and experimental techniques are used complementary to arrive at an optimal compact power system design. Deliver code to Army for evaluation.

PHASE III DUAL USE APPLICATIONS: Developments in compact fuel cell power systems will have immediate impact on a wide range of military uses as well as commercial power sources such as computer power, emergency medical power supplies, recreational power, etc...

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KEYWORDS: hybrid power system, fuel cell, soldier power, compact power

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

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 3.5.b.(7) of the solicitation.

OBJECTIVE: A myriad of new and enabling biotechnologies have emerged in recent years that could revolutionize the production of recombinant proteins in bioengineered organisms. The objective of this STTR is the application of new technologies for a rapid, cost-effective, accumulation system to produce recombinant and engineered proteins for civilian applications as well as for CB detection, decontamination, protection, and biosensor development

DESCRIPTION: Recombinant proteins are generating enormous interest in civilian applications as well as in areas of chemical and biological defense. Anticholinesterase nerve agents, such as organophosphates and carbamate toxins, can be effectively sequestered and neutralized by the enzyme, acetylcholinesterase. For defense against bacterial pathogens, rigorously targeted enzymes, called lysins, have been developed for limiting the spread of infections, protecting mucosa surfaces, and destroying specific pathogenic bacteria before and following disease development. The high specificity of humanized antibodies can be used for neutralizing toxins and for application in biosensors and biodetectors. Some biological fibers have remarkable physical properties that are superior to synthetic polymers.

Biotechnology has been particularly successful in identifying features of proteins for chemical and biological defense, as well as for civilian applications in industry, agriculture, and medicine, where protein drug development remains one of the fastest growing areas in pharmaceuticals. Properties such as enzymatic activity, self-assembly, extraordinary specificity, photoresponsiveness, elasticity, biodegradability, adhesiveness, high tensile strength, etc., can be engineered and tailored into proteins for unique applications. However, the cost of producing those proteins remains high, and this severely restricts biotechnological exploitation of the many beneficial properties of recombinant proteins.

A myriad of production difficulties account for the high cost of manufacturing bio-engineered proteins. Some of these problems include: low expression rates; expensive purification protocols; potential for viral or bacterial contamination; aggressive proteolysis in the producing system; low or variable transfection rates; long development times for the production system; insolubility of the engineered protein; and protein misfolding. While these problems appear formidable, new technological developments could remediate many of these shortcomings, and significantly reduce high production costs.

Directed integration of genes for specific protein sequences and highly responsive expression systems has been developed. Fusion protein technology has been perfected for facile purification of recalcitrant proteins. Genome sequencing of many organisms has made available vast, new information resources. Taken together, these as well as many proprietary developments have application not only in creating new recombinant proteins, but in building a very cost-effective production system.

The technology to be developed under this STTR would have military and civilian importance. A highly cost effective recombinant production system could have revolutionary impact on the synthesis of bioengineered proteins and hybrid materials possessing uniquely tailored properties. This STTR would develop the technology to meet the demand for low-cost supplies of uniquely bioengineered protein.

PHASE I: The collaboration and integration of specialists in the fields of molecular biology, plant or animal physiology, genetics, microbiology, and biochemistry would be utilized to identify the most suitable of the new technologies for application in the cost-effective production of bioengineered proteins. A production strategy would be developed and applied to the formation of a specific recombinant protein. Emphasis would be placed on the low cost, short development time, versatility, and quantity of protein to be produced. Successful demonstration of reproducible host transfection with a vector containing the structural gene for an engineered protein would be a major deliverable for Phase I.

PHASE II: The information and experience gained in Phase I would be used to apply the technology in the production of recombinant proteins. Demonstration of the ability to produce a variety of proteins that would be cost-effective and suitable for military use would be the major objective of Phase II. As a verification of the success of the project, a protein that would be suitable for military use would be selected with the cooperation of Army scientists. Analyses of the structure and activities of the proteins should authenticate the viability of the production system. Cost analyses would be prepared and compared to current technologies.

PHASE III DUAL USE APPLICATIONS: In collaboration with Army scientists, the recombinant proteins would be tested, developed and shown to be suitable for field applications in various medical or biowarfare scenarios. Technology transfer for commercial development would be pursued. The unique new protein synthetic systems would have civilian applications in the production of: highly purified humanized antibodies for passive immunization and neutralization of invasive proteins in bacterial and viral infections; bioengineered proteins for medical sutures; enzymes for stereospecific synthesis or modification of high value pharmaceuticals; structural proteins that have been engineered for the organization of nanostructures; insoluble animal proteins with high tensile strength or impact absorption in passive restraint systems; photoresponsive proteins for ultra high density data storage modules; and proteins that are stable and able to function at high temperatures or high osmotic conditions.

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KEYWORDS: bioengineered proteins, bioproduction systems

A06-T016 TITLE: Gamma Ray Array for Passive Detection of Hidden Objects

TECHNOLOGY AREAS: Sensors, Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To determine the feasibility by simulation and simple measurements of the use of natural background radiation to see hidden objects in buildings and below ground. If feasibility is proven, then the Phase II objective would be to design, build, and test a detector array for imaging natural background radioactivity in order to build up a picture of structures of interest.

DESCRIPTION: Energetic particles are spontaneously emitted by small concentrations of naturally occurring radioactive elements that are present in soils, minerals, and construction materials. Current surveillance methods employing radar or infrared radiation can be somewhat limited in their abilities to provide information regarding the location of unseen objects of interest which may be in building interiors or subsurface locations. Highly energetic radiation provides a relatively unexplored opportunity for probing into fixed structures to examine anomalies which would indicate man-made structures, tunnels, or other objects which may pose threats to security. The use of an array detector facilitates detection of such objects to potentially obtain a conceptual illustration of what is hidden.

Levels of background radiation vary due to geographic location and other factors. However, studies of the range of energies available in the natural background indicate that the primary range of interest would be from 50 to 150 KeV since much of the energy produced by natural background radiation is in this range. On the other hand, the atmospheric transmission and ability to penetrate other material is diminished at this energy so higher energies may be necessary for useful imaging. Naturally occurring potassium, which is fairly common, generates a gamma ray at 1.460 MeV which may also be used. The function of the proposed detector array would be to monitor a specific area and look for abrupt changes in small localized areas. Such changes would be indicative of potential structures or objects that would otherwise be hidden from view. Angular resolutions of ten arc minutes have been reported by astronomical instruments that use this energy range.

The challenge for this project is to determine if gamma rays can provide useful information to detect hidden objects. This would include mapping the interior of buildings from a reasonable standoff distance on the outside and the discovery of tunnels that may be two to six feet under ground.

PHASE I: Determine the feasibility by simulation and simple measurements of using natural radiation from nuclear decay for detection and imaging of hidden objects. The measurements should determine the degree of uniformity of the background radiation at several locations. The simulation would determine the optimum wavelength for imaging with reasonable gamma ray detectors and optics. The simulation should consist of determination of the overall efficiency including count rate, potential resolution both range and angular, and ability to see through common wall materials and natural soil. Other factors to determine would be size and cost of a potential detector array.

PHASE II: Utilize information gathered from Phase I simulation to optimize detector system performance for imaging hidden objects. The Phase II effort should include design, construction, and evaluation of a prototype system suitable for field testing.

PHASE III DUAL USE APPLICATIONS: The technology developed and enhanced under this topic serves as a next step in the effort to move above and beyond the capabilities of conventional x-ray imaging. The remote sensing capabilities of large objects have potential uses in screening of suspicious cargo as well as other airport or seaport screening. The detection system could also be useful in archeological excavations or in investigations of structure failures or accidents. If passive detection using natural background radiation doesn't work, a potential related implementation would involve a radiation source to see through obstacles.

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KEYWORDS: see-through-the-wall, tunnel/bunker, gamma rays, radioactivity

A06-T017 TITLE: Light Filament Sensor

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 3.5.b.(7) of the solicitation.

OBJECTIVE: The goal of this research and development is to create a new kind of sensor that will use light filamentation to produce white laser light, illuminating the target with broad, coherent radiation.

DESCRIPTION: Over the past few years light filaments have been shown to exist [1], and the theoretical modeling has improved.[2] When a laser beam above a critical intensity propagates through the atmosphere, Kerr self focusing occurs, increasing the intensity until plasma formation occurs, which tends to defocus the beam. Under the right conditions these two effects “balance,” and a propagating light filament is produced. An interesting property of the filament is that it produces “white laser light,” coherent radiation broadened over the entire visible spectrum, or beyond. This project will capitalize on this property, using the light filament to irradiate a distant target. Since the target is illuminated with coherent radiation at all wavelengths, the agents will radiate at their characteristic frequency. The kinds of objects or substances to be detected are any that are important to Army needs, such as explosive materials, and chemical or biological agents. The sensor may also be used to determine the chemical composition of objects.

PHASE I: Describe how the light filaments will be made, specify the source laser frequency and intensity, and estimate the spectral power on target. Describe the kind of sensor to be used to spectroscopically determine the materials of the target. It must be clearly demonstrated in Phase I that a light filament can be made and will propagate at least several meters. Without this, the project cannot go on to Phase II.

PHASE II: The company should build a prototype that will demonstrate the following: It should be shown that light filaments are created and their propagation distance should be known. It should also be shown that white laser light is created. The filaments should be directed to a target that is irradiated with the beam, and the target materials should be excited from the broad coherent spectrum. A detector should be able to identify the substance, or determine the chemical composition of the materials.

PHASE III DUAL USE APPLICATIONS: The ultimate goal of this research is to produce a revolutionary new kind of sensor/detector. It will have the ability to create white laser that covers the entire visible spectrum or beyond, and put that beam on a remote target. This sensor will have applications in homeland security and airport screening, as well as identification of toxins or toxic residue in industrial or post military settings.

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KEYWORDS: light filament, sensor, white laser

A06-T018 TITLE: Analysis and Visualization of Large Complex Multi-Step Cyber Attack Graphs

TECHNOLOGY AREAS: Information Systems

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 3.5.b.(7) of the solicitation.

OBJECTIVE: This STTR aims at the development of a highly effective analysis and visualization system that can be used to display and analyze potentially very large and complex graphs of multi-step cyber attacks against networks, based on network vulnerabilities, connectivity, and attacker exploits. The visualizations need to include all possible network attack paths, while still keeping complexity manageable. The system also needs to provide a range of levels of detail, from high-level overviews to low-level details, with easy navigation between levels. The goal of this system is to transform large quantities of network security data into real-time actionable intelligence, which can be used to provide guidance on network hardening to prevent attacks, to perform real-time attack event correlation during active attacks, and to formulate post-attack responses.

DESCRIPTION: Within DoD information infrastructures, general-purpose computers are used widely for many mission-critical functions. But security is often not given adequate priority in the design of general-purpose computers, and vulnerabilities in one system can lead to compromise across the network. Cyber attackers have been exploiting vulnerabilities in unexpected ways, to incrementally penetrate the network and compromise critical systems. It is important to develop the capability to manage risks and significantly reduce the impact of attacks by knowing the possible attack paths through our networks. To achieve this goal, raw security data needs to be transformed into multi-step cyber-attack roadmaps that provide real-time situational awareness and actionable intelligence. Progress has been made in generating such attack roadmaps automatically, using information from network scans, cyber-vulnerability databases, etc. However complex cyber attack graphs showing all possible attack paths are very hard for human comprehension.

New analysis and visualization techniques [1, 2] are needed to help make complex attack graphs more comprehensible for analysts to perform correlation, prediction, and hypothesis of attacks effectively. These techniques must reveal graph regularities, extract important features such as bottlenecks and densely-connected subgraphs, and provide situational awareness at a glance. Multi-step reachability across the network needs to be shown in order to identify the impact of network configuration changes. Further, the analysis of intrusion alarms within the context of network vulnerabilities needs to be supported. The analysis and visualization tool will provide interactive multi-resolution views such that an analyst can first obtain high-level overviews quickly, and then drill down to specific details. Through interactive filtering of attack graphs according to selected criteria, the attack subgraphs of interest can be extracted and displayed. The developed techniques need to have sufficiently low computational complexity, for scalability to larger and/or less secure networks.

PHASE I:

1. Determine the most applicable technologies and architectures for implementing a comprehensive multi-step cyber attack analysis and visualization system.
2. Evaluate current network scanning tools and vulnerability databases for their potentials in building the necessary input models.
3. Develop and develop system architecture of the analysis and visualization system. Provide a laboratory demonstration of a prototype implementation of the system.

PHASE II:

1. Extend the system prototype to a working system, and demonstrate its capabilities in a testbed network. Field trial on DoD networks is highly desired.
2. Demonstrate system scalability, as a function of network size, topology, and degree of vulnerability.

PHASE III DUAL USE APPLICATIONS:

1. Enhance the developed system into a mature commercial product, for integration into operational military, intelligence community, and/or commercial network(s).

COMMERCIALIZATION POTENTIAL:

The analysis and visualization system has applicability to civilian networks where integrity of information and availability of services is critical. Examples of civilian uses include in the areas of finance, medicine, and communications.

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KEYWORDS: information security, attack graph analysis and visualization, network vulnerability analysis, attack correlation

A06-T019 TITLE: Development of On-Demand Non-Polar and Semi-Polar Bulk Gallium Nitride Materials for Next Generation Electronic and Optoelectronic Devices

TECHNOLOGY AREAS: Materials/Processes, Electronics

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 3.5.b.(7) of the solicitation.

OBJECTIVE: The goal of the research is to identify manufacturing processes, which on demand, are capable of production of non-polar and semi-polar nitride substrate materials that demonstrate low defect density ($<10^7$ cm⁻²), improved doping control, improved carrier concentration engineering, lower contact resistance, and higher hole mobility.

DESCRIPTION: Historically, conventional growth of gallium nitride (GaN) results in a polar oriented surface, that is, it results in a built-in electric field near the surface or interface. These built-in fields affect electron and hole recombination. A new class of nitrides has been grown with a semi-polar or non-polar surface orientation. These surfaces have crystal symmetry which is quite different from the conventionally grown surfaces. At the same time, the development of advanced GaN and other III-nitride and wide bandgap semiconductor devices is gaining importance for a broad range of military sensor and radar applications. Record performances have been obtained in millimeter-wave and radio-frequency transistors built from III-nitride device layers grown epitaxially on silicon carbide (SiC) and other foreign substrates. However, several technical issues remain which are considered to be due to the lack of availability of a high quality bulk GaN substrates. The lattice and thermal expansion mismatch associated with the foreign substrate SiC results in very high dislocation densities in the GaN device active region. The development of low dislocation density single crystal GaN boules which can be oriented in any direction on demand represents an important step towards improving the GaN active region crystallinity. Thus electronic and optoelectronic device performance should result in a more efficient energy output to input ratio. Further, recent research suggests that the historically difficult to grow p-type doped layers will be possible and will be more conductive. The more conductive materials result in less heating and thus lower resistance. There is also indication of improved laser performance resulting from the improved wavelength stability with the lower drive current. Most importantly, with the ability to make non-polar and semi-polar oriented GaN substrates, the device engineer will have the ability put charge in the device layers where it is needed and to remove it where it is not needed. Thus, this capability will enable new device designs to reach higher hole concentrations and higher hole mobility, which could enable development of better p-type contacts, development of complimentary GaN transistor circuits, and development of high performance heterojunction bipolar transistors. That is, this new capability is expected to give rise to improved device performance, greater reliability and longer lifetimes. Possible promising approaches to development of non-polar and semi-polar GaN substrate materials include the ammonothermal growth, hydride vapor phase epitaxy, and sublimation growth, all of which are actual bulk growth approaches that in principle can produce low defect density boules. Thin layer epitaxial substrate growth approaches that do not result in production of GaN boules that can be sliced are not considered viable for producing non-polar and semi-polar GaN with low enough dislocation densities ($<10^7$ cm⁻²).

PHASE I: Investigate and demonstrate innovative growth methods to achieve semi-polar and non-polar nitride materials. Analyze the feasibility of producing low defect density ($<10^7$ cm⁻²) single crystal gallium nitride (GaN)

substrates with on demand non-polar and semi-polar orientations. Develop prototype GaN materials that together with a detailed engineering and manufacturing cost structure analysis to show the ultimate commercial viability of the approach for on demand manufacturing of low defect density substrates.

PHASE II: The small business should implement the manufacturing processes identified in phase I. This should include both growth and characterization of the semi-polar and non-polar surfaces and interfaces of the nitride materials. Implement the development of low defect density ($<10^7$ cm⁻²) single crystal gallium nitride (GaN) substrates of arbitrary orientation including non-polar and semi-polar directions. Demonstrate repeatable on demand manufacture of non-polar or semi-polar substrates at one or more orientations for substrate lateral dimensions in excess of 1 cm. Explore major cost and reliability issues associated with manufacturing of commercially viable substrates of three-inch diameter or greater.

PHASE III DUAL USE APPLICATIONS: This manufacturing process will offer the opportunity to better control and optimize material properties to enable next generation electronic and optoelectronic devices. This effort is intended to lead to the development of a portfolio of low defect density GaN substrates of user-selectable orientation. These substrates are expected to enable critical advances in the performance and reliability of a broad range of electronic and optoelectronic III-nitride devices of strong interest for homeland security, homeland defense, and commercial applications. For example, gallium nitride high-electron mobility-transistor (HEMT) devices provide the relatively high power density and efficiency necessary for high-power phased array radar, electronic warfare, missile seekers, and communications systems. Commercially, gallium nitride is also highly desirable to make better HEMTs, enhancement mode HEMTs, and higher quantum efficiency optical devices, that is, lasers, light emitting diodes, and UV/VIS detectors. Thus, the commercialization stage will include demonstration of the many advantages afforded by successful development of such substrates, followed by launch of improved and new III-nitride devices into the commercial sector.

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KEYWORDS: on demand manufacturing, on demand production of semi-polar nitride surface and interface, on demand production of non-polar nitride surface and interface

A06-T020 TITLE: Ranging and Acuity Enhancement for Terahertz Imaging Spectrometers

TECHNOLOGY AREAS: Electronics

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 3.5.b.(7) of the solicitation.

OBJECTIVE: To design, build and demonstrate a new class of THz (or sub-millimeter-wave) imaging spectrometers that possess ranging and acuity enhancement enabled by electronic modulation techniques. Applications include remote monitoring of chemical, biological, and energetic agents as well as the remote detection of concealed weapons and explosive devices.

DESCRIPTION: Standing-wave effects almost always contaminate measurements and images in high repetition rate or continuous-wave (CW) sub-millimeter-wave and THz systems that use active, coherent illumination, frustrating attempts at spectroscopic sensing and lowering acuity of the image. To promote advancement of these systems for remote detection, generalized techniques and approaches for mitigating the effects of standing waves in such systems are an absolute necessity. While the promise of sub-millimeter-wave and THz spectrometers for remotely monitoring chemical, biological and energetic threats and the remote detection of concealed weapons and explosives is becoming a reality, most single-pixel measurements and multi-pixel images made with active, coherent

illumination of the target are contaminated by standing-wave effects. In pulsed THz spectroscopy, mitigating these effects is easily achieved through the use of thick sample windows or by time gating[1-3], but this is a laboratory technique, and usually involves relatively low pulse repetition rates, lowering the average power and increasing data acquisition times. Faster repetition rates—approaching CW—and coherence between source and receiver are all desirable for improving signal-to-noise ratios, but these come at the expense of standing wave effects [4] – i.e., the sub-millimeter-wave and THz equivalent of laser speckle. Reducing these effects will enable not only clean, interpretable images but will also enable accurate ranging, critical for field-deployable sensing.

New approaches for optical time-domain reflectometers use Golay codes to modulate each transmitted laser pulse. Other researchers have simply used pseudo-random bit stream (PRBS) codes that are easily generated in the lab. These techniques have improved ranging and reduced standing-wave ambiguity in optical systems and have charted the course for new breakthroughs in THz system technology [5]. Specifically, the translation of these modulation techniques to sub-millimeter-wave and THz regime, while at the same time minimizing the effects of modulation on their already-limited output power could have fundamental enabling benefits for an array of remote monitoring applications. Indeed, this type of technology would have immediate and broad-based application in the laboratory and in field-deployable sub-millimeter-wave and THz imaging spectrometers.

PHASE I: The Phase I effort should identify and analysis potential techniques that can be utilized to mitigate standing-wave effects for pulsed and/or CW sub-millimeter-wave and THz imaging spectrometers with a preference for approaches that are generally applicable for addressing two or more different spectrometer types (e.g. mm-wave vector network analyzers and fast-pulse time-domain THz systems). The Phase I effort should establish the initial designs, plans and preliminary measurements required to substantiate a demonstration plan in the future and to make predictions for range and acuity enhancements.

PHASE II: The Phase II effort should build and demonstrate a prototype system that would be capable of mitigating standing wave effects in THz-frequency spectral imaging applications of interest to the U.S. Army and DoD. Relevant applications could include, but are not limited to, remotely monitoring for chemical, biological and energetic threat agents, and/or the remote detection of concealed weapons and explosive devices. The Phase II demonstrations should document the effectiveness (i.e., in terms of range and acuity enhancement) of the system in realistic battlefield situations and also give indications as to the advantages for laboratory investigations.

PHASE III DUAL USE APPLICATIONS: The initial targets for the proposed technology is threat detection and monitoring, which includes several dual use applications. The dual use opportunities for this technology include: remote monitoring of chemical, biological and energetic materials in the air and on surfaces, and the detection of concealed weapons and explosive packages. This technology would also have applications to quality control monitoring of package commercial items and in processing monitoring in chemical manufacturing.

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- 2) A. G. Markelz, A. Roitberg, and E. J. Heilweil, "Pulsed terahertz spectroscopy of DNA, bovine serum albumin and collagen between 0.1 and 2.0 THz," *Chemical Physics Letters*, vol. 320, pp. 42-48, 2000.
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KEYWORDS: terahertz, spectroscopy, imaging, standing waves, chemical, biological, energetics, weapons, explosives

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 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop either a new substrate or new process for reduction/mitigation of dislocation defects that results in improved performance and operability of Longwave Infrared (LWIR) HgCdTe sensors.

DESCRIPTION: Infrared (IR) sensors are important to all services of the DoD for applications ranging from night vision to threat warning. In the case of HgCdTe, which is the most prevalent semiconductor used in high performance applications, the material is deposited on lattice-matched substrates. These substrates are single-source, expensive and limited in size. Deposition on lattice-mismatched substrates, in particular silicon, can result in up to a 200% increase in reliability and an order of magnitude reduction in cost. However, in cases of lattice mismatch between the layers and substrate, defects can arise with significant and deleterious impact upon sensor performance. These killer defects predominantly take the form of micro-twins and dislocations. Sensors made from these layers usually incur a higher dark current penalty and reduced operability. Many growth and processing strategies have been devised to mitigate the effects of the dislocations and these efforts have reduced the level to the mid $10^6/\text{cm}^2$ dislocation density. Although this is manageable for some wider gap thermal sensors, as the band gap decreases to LWIR (Long Wave Infrared), the situation becomes untenable. The purpose of this STTR topic is to solicit proposals with either growth or processing solutions to the dislocation problem. The cause of these dislocations is not well understood, so modeling of dislocations and their sources must be a part of this effort. A model of the growth mechanics (time, temperature, deposition variables, materials, what defects are damaging, etc.) will lead to potential solutions and better control. A number of theoretical models have already been developed to describe the evolution of threading dislocation densities in mismatched semiconductor films. These models seek to quantify the motion and interactions of threading dislocations and their associated misfit dislocations as functions of known variables such as total mismatch strain, f , film thickness, h , or time. Early semi-empirical models were based on experimental observations of a general inverse dependence of threading dislocation density on final film thickness. More complex models that account for changing strain relaxation and dislocation-dislocation interaction mechanisms such as blocking, annihilation, and fusion have since been proposed. These models confirm the general $1/h$ dependence of dislocation density on thickness, and predict further reductions in density by removing dislocation blocking mechanisms that limit annihilation reactions. This work should couple the dislocation modeling results to actual sensor growth and processing to demonstrate the technology for either an engineered substrate that is lattice matched or a process that reduces/mitigates defects enabling improved IR sensors.

PHASE I: Show the feasibility of reducing or mitigating defects by modeling and demonstration of growth/processes to result in reduction/mitigation of defects.

PHASE II: Produce either a prototype engineered substrate or a growth/processing technique that results in improved IR sensors. Demonstrate the effectiveness of these by producing a LWIR HgCdTe sensor made from a revised growth/processing routine that takes advantage of improved techniques for mitigating dislocations. This phase will involve a laboratory prototype and lab testing.

PHASE III DUAL USE APPLICATIONS: Demonstrate reproducibility of process and/or substrates to enable transition to producers of HgCdTe focal plane arrays.

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3) HgCdTe infrared detector material: history, status and outlook A Rogalski Institute of Applied Physics, Military University of Technology, 2 Kaliskiego St., 00-908 Warsaw, Poland Received 10 November 2004, in final form 13 April 2005 Published 22 August 2005 Print publication: Issue 10 (October 2005).

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KEYWORDS: dislocation, dislocation sources, LWIR sensors, plasticity, micro-twins, dark current

A06-T022 TITLE: Pathogen Concentration from Complex Water Supplies

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

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 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop an inexpensive, lightweight, system for concentrating pathogens from potable water supplies.

DESCRIPTION: Detection of pathogens in product and source waters will require the capture, concentration and recovery of pathogens to present to a detection technology. Tangential flow, electrophoresis, charge/mass separation have been looked at in the Joint Service Agent Water Monitor program. COTS based membranes can be used to filter 4L of water in 4 minutes with an estimated recovery of 80% of seeded Bacillus subtilis spores from tap water. Recent advances in tangential flow filtration, field-flow fractionation, and electrostatic concentration have pushed pathogen concentration technologies forward to where it is now feasible to consider commercial devices. Technology is sought to maintain the size (suitcase size and smaller) of current technologies, while increasing the starting volume to 1000L or more, and improving pathogen recovery rates without the use of additional liquids (such as fetal calf or bsa) to coat the membranes. Technology should demonstrate the potential to provide rapid (10 min or less) recovery from field drinking water without the use of extra buffers or reagents in the field. This suggests the filtration material should be self-contained, but all new and novel ideas are welcomed.

PHASE I: Design and build a laboratory breadboard system for concentrating pathogens from potable water supplies. Demonstrate a 50 to 1 concentration of Bacillus Subtilis in less than 10 minutes from potable water.

PHASE II: Design and build a prototype system for concentrating pathogens from potable water supplies. Demonstrate a 1000 to 1 concentration of Bacillus Subtilis in less than 10 minutes from potable water

PHASE III DUAL USE APPLICATIONS: first responders such as Civilian Support Teams and Fire Departments have a critical need for a small reagentless BW agent detection system. Such as system would be idea for protecting post office facilities.

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KEYWORDS: pathogen concentration, potable water, tangential flow, electrophoresis, charge/mass separation

TECHNOLOGY AREAS: Chemical/Bio Defense

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OBJECTIVE: This solicitation seeks novel technologies for near real time monitoring of the three-dimensional concentration profile of a challenge chemical or biological cloud presented to a developmental detection system. Innovations in open path sensing and sensor fusion technology are needed in order to query a three-dimensional spatial grid for the presence and concentration of a chemical or biological simulant released on a test range or in a large volume chamber.

DESCRIPTION: The potential for attacks involving chemical and biological warfare agents presents a significant threat to US military operations and interests. The Department of Defense (DoD) sponsors the development of advanced sensing technologies for both point and standoff detection systems that provide early warning for forces in the event of such an attack. A critical part of the development process is system performance validation. All DoD systems must undergo a rigorous testing and evaluation (T&E) process in order to be approved for transition to the field. Central to the T&E methodology is a capability of presenting a refereed challenge to the system using chamber or test range facilities in order to assess the system performance characteristics. This solicitation seeks novel instrumentation and methodologies for detecting, profiling, and mapping challenge vapor and aerosol clouds presented to such developmental systems in near real time and at high time resolution. Such a capability is subject to significant constraints: 1) it must provide time-dependent information about the challenge in a three-dimensional volume at concentrations below those that are detectable by the system under test; 2) it must perform its sensing and analysis without presenting a significant physical profile in the chamber or on the range; 3) it must be capable of specifically profiling clouds generated using both organic chemical vapor simulants and natural biological aerosol simulants; 4) it cannot be prohibitively expensive.

Infrared (IR) spectroscopy is a proven technology for the detection of vapor and aerosol species, and the DoD maintains a library of the quantitative cross-sections of chemical and biological agents and surrogates that are used in testing. New developments in IR sensing including low cost, high performance sources such as quantum cascade (QC) lasers and IR diode lasers afford a possible technology solution for this T&E problem. Current off-the shelf OP-IR systems are typically designed to employ an interferometer and a retroreflector to monitor a single column of air. In order to simultaneously monitor multiple spatial points in three dimensions, many such systems would have to be arranged around the refereed space. The result would be a bulky, high-maintenance, and high cost system that lacks an algorithm for deconvolving the information into the desired three-dimensional concentration map. New IR source technologies such as the QC or IR diode lasers may ultimately offer lower cost alternatives. Alternatively, low-cost infrared filters coupled to a high temperature source to perform a similar function. This solicitation is open to any sensible approach that would be capable of deriving concentration information from both chemical vapor clouds and biological aerosol clouds. A concomitant need for fusion of multiple sensor responses and computational tomography (CT) or other analysis algorithms is also implied and can be addressed by advances in the medical and materials imaging fields.

Several benefits would accrue from the development of advanced referee sensors. Most importantly, such sensors would exploit the latest developments in scientific research on novel infrared laser sources such as the QC lasers or IR diode lasers, advanced materials for optical filters in the IR, and advanced signal processing methods. The capability would be of value to industrial operations that have a need for real time vapor and aerosol process monitoring, such as that used in the preparation of advanced materials for the electronics industry. In addition, next generation sensors for military and homeland security applications would be expected as the infant technologies improve and pave the way for high performance, low cost detection platforms.

PHASE I: Demonstrate feasibility of a proposed concept sensor network grid that affords near real time concentration profiling in three dimensions. In the initial study, a scalable 3x3x3 cube should be considered that defines 27 points in space at which a concentration is profiled. The Government will furnish quantitative infrared

cross-section information to performers on several typical simulants: dimethyl methyl phosphonate, and triethyl phosphate, model organophosphates used to emulate nerve agents, glacial acetic acid, a commonly used low volatility chemical, and Bacillus globigii, a model bacterial spore used to emulate anthrax. Develop and execute system model (concept effectiveness analysis) that details the physical implementation of the optical grid and its associated expected limits of detection. Additional descriptions of any innovative signal processing hardware and/or software should also be described in the Phase I study as appropriate.

PHASE II: Design and construct an engineering prototype to be demonstrated at the end of this phase. The prototype will be sufficiently refined so that effectiveness of the embodied concept in detecting chemical and biological simulants can be evaluated. During this phase the theoretical concept effectiveness analysis from Phase I would be refined into a prototype effectiveness analysis using measured performance parameters of the prototype device.

PHASE III DUAL USE APPLICATIONS: Perform a technology demonstration of the prototype device in association with a Transition Readiness Evaluation or other DoD-sponsored field trial. These field trials would constitute the basis for additional modifications as well as any subsequent procurement decision. In addition, develop private sector applications and implementations of the core sensor functionality.

PRIVATE SECTOR COMMERCIAL POTENTIAL: The proposed technology would be useful in commercial applications that involve the profiling of concentrations of airborne chemicals. Such processes as chemical vapor deposition (CVD) and pharmaceutical respirable drug dosing would benefit from a referee/measurement capability that affords detailed concentration profiles.

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KEYWORDS: Infrared detection, open-path sensor, chemical agents, biological agents, quantum cascade laser, infrared diode laser, computational tomography, signal processing

A06-T024 TITLE: Colorimetric Sensors for Chemical and Biological Warfare Agents

TECHNOLOGY AREAS: Chemical/Bio Defense, 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 3.5.b.(7) of the solicitation.

OBJECTIVE: Construct litmus paper-like colorimetric sensors for detection and identification of chemical and biological agents in water. The sensors should be biocompatible, biodegradable, rapid, autonomous, cost-effective, and easily interpretable for soldiers in the field. Stability under extreme environments such as hot, dry and dusty arenas is also important for field operation. The sensor design should be general and can be used to detect multiple chemical and biological warfare agents simultaneously without an extensive support system. The sensor response should be immediate to give distinct visual color changes in the presence of the targets.

DESCRIPTION: The primary intended user is the soldier in the field where rapid assessment of potable water is critical for human health and safety. Despite the progress, this area still requires laboratory research to carry the ideas to fruition. Successful demonstration of the colorimetric sensor will create a fieldable technology for commercialization. Being able to identify the composition of unknown substances accurately and quickly is particularly important for soldiers in the battlefield and for homeland security applications. Colorimetric test strips employed via simple dip test into the aqueous sample are very attractive as the detection signals can be observed by the naked eye without a bulky, expensive or complicated support system. In addition, soldiers without chemistry backgrounds can easily and rapidly interpret the results. Preferably, such sensors should be able to detect

contaminants in a broad range of media, such as in water or blood serum. The sensors should also be made of materials that are biocompatible, biodegradable, and safe for soldiers to use in the field. The same sensing platform should be adaptable to detect many substances of choice. Currently, there is no product that can be used for this purpose. Although emerging technologies such as micro-electro-mechanical systems (MEMS) show promising potential for such sensing applications, the needed power supplies, ancillary equipment, and troubleshooting requirements hinders their field applications. Combinatorial biology has resulted in nucleic acid molecules known as DNA/RNAzymes and aptamers that can recognize a broad range of substances, ranging from small organic molecules to proteins and even anthrax spores. Molecular recognition by these nucleic acid molecules demonstrates remarkable specificity. As a result, false positive or false negative results can be avoided. Recent advance in bionanotechnology has shown promise of transforming those DNA/RNAzymes and aptamers into fluorescent and colorimetric sensors (1,2). If this emerging technology can be further developed, the detection of a number of chemical and biological warfare agents simultaneously can be realized and the same technology can be applied to construct sensors for drinking water protection and ground water monitoring.

PHASE I: Develop individual colorimetric sensors for chemical and biological agents or simulants using either previously developed aptamer sequences or newly downselected sequences. Demonstrate proof-of-principle reaction and detection behavior for aptamer based colorimetric test strips. The sensors should be cost-effective, have a long shelf life, and should meet all other requirements for standalone sensors such as specificity, sensitivity, simplicity, and speed. The sensor design should be general and can be used to obtain sensors for other substances of interest.

PHASE II: Create colorimetric test strips that combine multiple embedded aptamers for detection of a variety of contaminants with a single dip test. Generate the prototype test strip and test its field performance on laboratory samples and on complex environmental water samples. Prove selectivity and robustness for field use.

PHASE III DUAL USE APPLICATIONS: This effort will result in enhanced sensor performance for rapid response and unambiguous detection. Warfighter readiness, survivability and sustainment capabilities will benefit from success in this research. The primary intended user is the soldier in the field where fast detection and response is critical. Continuous monitoring and rapid assessment of potable water is necessary for soldier health and safety. Because of the generality in design, such sensors can be used beyond military applications since there is always a need for detection and identification of chemical and biological agents in water, even for household applications. The same technology can also be adapted to construct sensors for many other important substances, such as drugs, toxins, or heavy metal contaminants. These can be used in the civilian arena for drinking water monitoring, environmental assessment, and rapid medical testing.

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KEYWORDS: sensors, colorimetric, chemical biological detection

A06-T025 TITLE: Detection of Explosive Materials Using Encapsulation of Fluorescent Specific Microorganisms as Bioprobes

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 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this STTR is to investigate increasing the accuracy and precision of explosives in soils by designing a portable biofunctional device that incorporates altered organic and/or inorganic materials. This new and potentially improved device can be used to detect / monitor explosives on ranges and battlefields to support BRAC and other clean up efforts. Remote placement of sensors and detection of contaminants is ultimately desired. It would also help to reduce cost for cleanup efforts. The matrix of the probe would need to be experimentally designed to withstand environmental factors such as pH, temperature, soil moisture, and/or salinity changes.

DESCRIPTION: There is a need for near-real time detection and location of explosives in small quantities for the reclamation of ranges under Base Re-Alignment and Closure guidelines. There is also a need to spatially determine the extent of explosives presence. Distributed placement of sensors is desired. One such approach for developing this detection system may include use of a synthetically designed membrane matrix that would act as a cage or encapsulation template wherein inorganic probes or modified microorganisms are adhered to the matrix for use in explosives detection and sensor recognition. A highly efficient matrix would allow proliferation of the probes, but not permit release of the (biological) probe into the environment. The bioprobe, for example, could be fluorescent, but is not limited to fluorescent illuminated detection. The active site on the membrane matrix containing the adhered probes would be in contact with the environmental contacts such as soil or water surfaces, upon contact with explosive indicators, the adhered probes would trigger a response for remote interrogation. The research in this effort will consist of a suitable membrane matrix and matching probe development integrated within a sample microcosm chambers for field deployment. The research will also include improving sensitivity of detection of explosives in soils and accuracy of the specific explosive compound at a site for clean up versus a generic nitroaromatic compound, which could lead to false positives.

PHASE I: Complete a conceptual design and demonstrate feasibility of a biofunctional membrane matrix explosives detection system that will be more accurate and precise than the latests explosive detection systems. The concept design should include: the target explosives and bioprobes, the membrane matrix upon which they are attached, and an encapsulation within which they are incorporated. As part of feasibility demonstration, it would be desirable to include tests of signal/probe preparations required for the detection of select explosives and/or explosive indicators.

PHASE II: Develop and demonstrate prototype system. Test under a range of controlled explosive material concentration releases in soils under various environmental conditions. Apply different analytical procedures for elucidating "harvested" tagged probes. Integrate global positioning with the unit for locating, time-stamping, and mapping detected explosives. Time stamping should provide the needed information for monitoring explosive transport and dispersal rates.

PHASE III DUAL USE APPLICATIONS: Such a device has broad dual use applications from monitoring environmental soil and water quality to expanded military uses including non-man portable range monitors. Additionally, drones may be adapted to distribute and monitor the chambers remotely.

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KEYWORDS: fluorescence, explosives, nanofibers, encapsulation, bioprobes

A06-T026 TITLE: Rapid Detection Nano-Sensors for Biological Warfare Agents in Buildings and HVAC Systems

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 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this research is to develop and test nano-sensor systems for real-time detection and identification of airborne biological warfare agents in buildings and heating ventilation and air conditioning (HVAC) systems

DESCRIPTION: Currently there is no real-time technology to determine if airborne biological warfare agents have been disseminated within buildings and HVAC systems. Conventional detection technologies require 30 minutes to 1 hour to detect the biowarfare agents. The building occupants are at risk during the time that they are exposed to the agents. The non-availability of the buildings during an attack is costly and can severely affect the execution of critical military missions. Therefore, there is a need to develop and demonstrate new technology that can both detect the presence of biological warfare agents and identify and quantify the pathogens. This effort will require the development of nano-sensors for accurate and sensitive detection of biological agents, such as: (1) bacterial spores (e.g., anthrax), (2) viruses (e.g., smallpox), (3) vegetative bacteria (e.g., plague), (4) bacterial toxins (e.g., ricin) in real-time (less than 1 minute) using nano-sensors that can be placed in strategic locations within buildings and HVAC systems and interfaced to central alarm HVAC control systems.

PHASE I: Determine the feasibility of using nano-sensors for rapid detection of biological warfare agents disseminated through the air in buildings and HVAC systems using nanosensors. The nanosensors could utilize the results of recent basic research on special semiconductor materials that have the capability to signal the presence of several specific biological warfare agents in real time. The nanosensors could be based on generation of unique optical signals, such as a specific wavelength of light, and the quantity of agent present could be determined from measurement of the intensity of the light. One example of the technology is the use of a fluorescence resonance energy transfer (FRET) phenomenon to produce change in light intensity in antibody-conjugated quantum dot sensors. The efficacy of the sensor technology needs to be determined using simulants for the following classes of biological warfare agents in a multiplexed situation: (1) bacterial spores (2) viruses (3) vegetative bacteria, (4) bacterial toxins.

PHASE II: Develop technologies for real-time detection of airborne biological warfare agents (such as smallpox, anthrax, or botulism) in buildings and HVAC systems based on the generation of pathogen-specific optical signals, which can activate an alarm system. Demonstrate the capability of the sensor to quantify the air concentration of pathogen detected.

PHASE III DUAL USE APPLICATIONS: The technology to be developed under this research can be expected to enhance the capability to continue the military mission and protect people inside buildings during airborne biological warfare agent attacks. Candidate customers are designers of buildings on military installations as well as the occupants of the buildings, especially military critical facilities that must ensure the continuity of the mission during the biological attack. The use of real time detection of airborne biological warfare agents from a terrorist attack will also enable timely response and countermeasures to the threat that results in lower casualties in civilian buildings.

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KEYWORDS: biological warfare agent, nanotechnology, optical sensors, real-time detection, nanoparticles, fluorescence resonance energy transfer (FRET)

A06-T027 TITLE: Prediction of the Degradation of Composite Materials for Emerging Army Facilities

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 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this research is to develop a methodology, based on mechanistic models, for predicting the long-term durability (25 years) of composite materials to be used in military facilities.

DESCRIPTION: Composite materials are being increasingly used in improving the rehabilitation and durability of the Army building systems, seismic upgrading and repair, and improved building designs. For example, carbon fiber epoxy matrix composites are used in wet-layup form as appliqués and wraps for these purposes. The reports of performance of these thermoset composites from the field are mixed. In some cases, these composite materials have not exhibited satisfactory long-term performance, i.e., over a 25 year period. There are heightened concerns related to the overall durability of these materials, especially as related to their capacity for sustained performance under harsh and changing environmental conditions under load. Currently, no capability exists for reliably projecting future state and conditions of composites used in emerging Army facilities in various environments. A means of predicting the long-term performance of the composite materials based on accelerated laboratory testing and degradation models is needed. Loading conditions and mechanical properties of interest (including creep, compression, strength, stiffness, and ductility) must be considered for each type of composite depending upon its specific application.

PHASE I: Determine the feasibility of using laboratory based accelerated testing of emerging carbon fiber epoxy composite materials to predict the long term performance of the materials in wet-layup form for strengthening building construction and other structural applications. The testing should include simulation in standard or specially constructed laboratory test chambers that simulate the effects of field exposure to the synergistic degradation effects of the weather, including ultraviolet radiation from sunlight, under a variety of situations that include various loading conditions and extreme atmospheric environments, viz., hot/dry, hot/wet, cold/dry and cold/wet. Determine the feasibility of using models based on experimentally determined fiber/matrix degradation processes to predict the performance and service life.

PHASE II: Develop models of composite materials degradation phenomena including: (1) glass transition temperature depression, (2) cure progression threshold, (3) relaxation and creep threshold, (4) chemical degradation of the matrix, (5) crack growth in fibers and (6) fiber/matrix failure. Develop detailed methodology to predict the long-term performance and service life of composite carbon fiber epoxy materials in seismic upgrading and repair, and improved building designs, based on accelerated testing and an understanding of degradation mechanisms.

PHASE III DUAL USE APPLICATIONS: The technology to be developed under this research can be expected to provide more durable design of military and civilian building and structures. Candidate customers are designers of buildings on military installations as well as the occupants of the buildings, especially military facilities that must remain structurally intact during seismic or blast events in order to ensure the continuity of the mission.

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KEYWORDS: composite materials, carbon fiber epoxy matrix, thermoset polymers, durability

A06-T028 TITLE: Minimally Invasive Device to Monitor Spreading Depression in the Injured Human Brain

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Minimally invasive device to monitor spreading depression in the injured human brain

DESCRIPTION: Secondary pathology is common in acute brain injury, resulting in delayed neurologic deficits, expansion of tissue loss, and death. The mechanisms of such patient deterioration remain partially unknown, but would be greatly advanced by a device to monitor cortical spreading depression (CSD), a major suspect in secondary pathology that can not be routinely monitored in patients at present.

CSD is a wave of transient metabolic and electrical failure which spontaneously propagates at 2-5 mm/min through peri-lesional gray matter of the injured brain with a wavelength of ~2 to 20 mm. During CSD, neuronal and glial cells depolarize for 40 sec to several minutes, resulting in a -20 mV shift in the extracellular potential, a longer-lasting 'depression' of EEG activity, cellular edema, increased metabolic demand/glycolysis, cerebral blood flow transients, and massive shifts in ion distributions. In animal studies, CSD mediates the development of brain injury, and parameters of CSD (e.g. timing, duration) correlate to injury progression and outcome (Back et al., 1994, 2000; Hartings et al., 2003; Rogatsky et al., 2003). CSD is a harbinger of impending tissue death, as these transient depolarizations cause damage and transition to terminal depolarization (Umegaki et al., 2005). CSD may represent the most severe type of brain seizure, yet is not manifested in clinical convulsions and can only be detected by monitoring affected tissue.

Presently, CSD is only monitored with subdural electrode strips in human patients requiring craniotomy for medical care (Strong et al., 2002). In these patients, CSD has a high incidence (~50%) across stroke, penetrating and traumatic brain injuries, sub-arachnoid hemorrhage, and arterio-venous malformations. However, the vast majority of brain-injured patients who are expected to experience CSD do not require craniotomy for medical treatment, and therefore are not candidates for this type of monitoring.

Thus, a device is required to permit monitoring of CSD that is non-invasive (preferable), or sufficiently 'minimally' invasive and low risk to justify use in most, if not all patients at risk for CSD. This is essential to permit clinical research on CSD and, eventually, continuous monitoring of CSD as a standard in patient care and possible guide for treatment. To detect CSD, such a device should be able to capture the unique electrical or chemical signature of spreading tissue depolarizations and permit monitoring continuously for several days with minimal logistic interference with other patient care. Methods to be employed might include 1) a microelectrode array to record micro-EEG and near-DC potentials, 2) a potassium-sensitive microelectrode to monitor for extracellular potassium transients unique to CSD, 3) near-infrared spectroscopy to monitor tissue oxy/deoxy-hemoglobin changes during CSD (Wolf et al., 1997), or 4) a scalp electrode array with sufficient spatial resolution and data processing routines to extract CSD events. These techniques are merely suggestions; more advanced bioengineering methods and modalities that are non-invasive would be advantageous.

PHASE I: The goal of this phase is to demonstrate the feasibility of detecting CSD with a minimally invasive technique. The method employed might be based on electrophysiologic recordings or changes in tissue oxygenation, blood flow, or ion concentrations. Proof-of-concept will be based on sensitivity, specificity, and ability to distinguish CSD from other neurophysiologic events.

PHASE II: The method in phase I will be used to develop a prototype device that is sufficiently minimally invasive or non-invasive to enable use in human patients with moderate-to-severe brain injury, including stroke, sub-arachnoid hemorrhage, and traumatic brain injury, who do not require craniotomy and, preferably, even those who do not receive an ICP monitor. The device should be able to monitor activity in peri-lesion or peri-infarct regions. The device should be sufficiently compact and low-profile to not interfere with normal patient care.

PHASE III DUAL USE APPLICATIONS: A minimally invasive monitor of CSD will have widespread application for care of neurologic and neurosurgical patients in both military and civilian sectors. Initially it will be applied in routine monitoring of patients with acute brain injury in order to clinically demonstrate the pathophysiologic correlates of CSD and the prognostic/diagnostic utility of CSD monitoring. It is envisioned to provide bedside, real-time assessment of injury maturation, as indicated by the emergency of repetitive CSD tissue depolarizations preceding terminal depolarization. This would serve as an indicator for pharmacologic or other therapies that would improve outcome. This device would have application in all cases of acute brain injury, including militarily relevant traumatic, penetrating, and ballistic injury, as well as those occurring with higher incidence in veteran and civilian populations such as stroke, migraine, and sub-arachnoid hemorrhage.

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KEYWORDS: brain injury, spreading depression, electrophysiology, electroencephalography, non-invasive

A06-T029 TITLE: Advanced Robotic Detection of Chemical/Biological Agents, Toxic Industrial Gases, and IEDs for Force Health Protection.

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical, Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Design and prototype an inexpensive compact, field portable, stand-off high-efficiency, rugged, integrated detection and identification system for chemical & biowarfare agents; industrial toxic gases, and chemical components of Improvised Explosive Devices (IEDs) and integrate it with one of the emerging family of Joint Architecture for Unmanned Systems (JAUS) compliant unmanned ground vehicles (UGVs) intended for medical force health protection and combat casualty care missions.

DESCRIPTION: The real-time detection and identification of bio and chemical warfare agents as well as potential toxic industrial gases and Improvised Explosive Devices (IEDs) is of paramount importance for protecting military medical first responders and their patients on the battlefield and for counter-terrorism response at home. Several

efforts are underway to leverage the emerging Army Future Combat System (FCS), DOD Joint Robotics Program (JRP), and PM Force Protection Family of Rapid Response Equipment (FIRRE) JAUS compliant UGVs for a variety of force protection missions including casualty location, assessment, protection and evacuation. Several of these UGV robots have been equipped with the Army Chemical School chemical and radiation detection package known as CHARS by the Navy Space & Naval Warfare Systems Center (SPAWAR) and subsequently tested with troops in the field to include combat operations in Iraq. The CHARS package includes three standard sensors: the MultiRAE hazmat environmental gas sensor, the Joint Chemical Agent Detector (JCAD) nerve, blister and blood agent sensor, and the AN/URD Radiac 13 gamma and neutron radiation detector. CHARS has been implemented with JAUS on several medical combat casualty location and evacuation robots so that potential chemical and radiation contamination can be detected by the robots prior to and simultaneously with casualty location, assessment and extraction. However, just as important to medical first responders is knowledge of the presence and potential exposure of casualties to biowarfare agents, toxic industrial gases and IEDs. No mobile robotic capability to detect and identify biowarfare agents in the field currently exists and no integrated capability exists that will enable detection of both chemical and bio-agents as well as industrial toxic gases and IEDs. Such a capability would enable combat medics and other first responders to monitor and detect multiple threat agents without risky exposure as well as aid in diagnosis. Several approaches to chemical agent detection have been attempted. Since most chemical and nerve warfare agents have extremely low lethal dosages and short reaction times, countermeasures require a detection system to: 1) rapidly respond to an incoming threat; 2) accurately determine the threat level with a minimal false alarm rate; 3) be low-cost, rugged, portable, and suitable for field operation. The system should be light enough to be carried by a single soldier or small robot; 4) be multiplexible such that multiple sensor heads should be connectable via wire or wireless to a sensing network. Since most of chemical warfare agents have short reaction times, an effective system should have a short reaction time (<1 second). To minimize the false alarm rate, the system must be able to detect multiple signature lines of warfare agents simultaneously with no significant added costs. Optical remote sensing is regarded as one of the best sensing technologies to detect trace chemicals in atmosphere and water. However, optical technology often suffers from high component and operational costs (i.e. tunable lasers) and is difficult to employ in dirty environments where visibility and light transmission is impaired. Recent advances in the fiber optical industry have led to a significant cost reduction in optical components and systems (Ref 15), making possible a new generation of inexpensive optical systems for high-sensitivity chemical sensing. Likewise, Raman spectroscopy has been recognized as an extremely useful method for chemical and gas sensing. However, the Raman cross-section for most chemical warfare agents is small. This leads to weak Raman signal, low detection sensitivity, long signal accumulation times, and requires high-power lasers with large power consumption. Recently, it has been demonstrated that Raman signals can be enhanced dramatically by using nanotechnology. Advances in last few years in the fiber optics industry have also made possible a low-cost and inexpensive laser to perform highly-efficient Raman spectroscopy. The sensitivity of the Raman spectroscopy could also be enhanced dramatically by using nanotechnology and therefore consume much less power than traditional Raman systems (Refs 16-18). As with chemical agents several previous approaches to field detection of bioagents include: light based fluorescence polarization (Ref 1), nanotechnology (Refs 2, 3, 14,) fiber optics (Ref 3, 4) biological recognition based on bacteriophage displayed peptide receptors (Ref 4), and fluorometric and light scatter spectra (Ref 5). While the technologies employed by these techniques are robust, the problem with current detectors is that in order to collect and process the samples, the first responder medic operators are potentially exposed to contamination or infection themselves. In addition to the agent detection and identification approach itself, other Research questions that need to be addressed include: 1) prototype design or adaptation of robotic manipulator(s) for collecting samples from air, water, soil, personnel, and exposed equipment; 2) miniaturization of prototype robotic sample collector and assay device(s) sufficient to be mounted on a small (<80 pound) UGV; 3) prototype design and implementation of sampling and assay application software via onboard and/or remote processors; 4) integration and implementation of JAUS compliant, command and control of the robotic environmental sampling tool and assay device on the base UGV communication system. JAUS is required to enable operation of the robotic sampling and assay device from any of the FCS or JRP UGV controllers.

PHASE I: Design prototype environmental sampling and assay payloads and integrate them with JAUS compliant tactical robots.

- 1) Design a prototype JAUS compliant robotic manipulator(s) for collecting samples from the environment (water, soil, and air) and from exposed personnel and equipment (e.g. a robotic arm that can both collect environmental samples and place the samples in the onboard assay device for analysis).
- 2) Design a prototype sample assay system utilizing a technology which can both significantly enhance agent detection and also be capable of being implemented on a small tactical robot (e.g. nanotechnology enhanced Raman

spectroscopy, light based fluorescence polarization, fluorometric and light scatter spectra, etc.) demonstrate dramatic enhancement of detection sensitivity, accuracy, and short reaction time (<1 second) for an integrated approach to detection and identification of militarily significant chemical and bioagents, industrial toxic gases, and IEDs (based on relevant chemical signatures). Instantiate the design for at least one potential chemical (e.g. Sarin) and one biological agent (e.g. anthrax) and one common IED component (e.g. TNT).

3) Formulate strategy for integration of the assay device(s) and environmental sampling tool(s) with JAUS Compliant communications and computer processing systems onboard a prototypical Future Combat Systems Small Unmanned Ground Vehicle (SUGV) (e.g. Packbot, Talon, Wolverine).

PHASE II:

1) Develop and demonstrate a prototype system with dramatic advancement in sensitivity, accuracy, and short reaction time (<1 second) for an integrated approach to detection and identification of militarily significant chemical and bioagents, toxic industrial gases and IEDs. Implement the design for multiple potential agents from each of the four groups: chemical, biological, industrial, and common IED components.

2) Develop and demonstrate JAUS compliant robotic manipulator(s) for collecting and processing samples from the environment (water, soil, and air) and from exposed personnel and equipment.

3) Integrate and demonstrate the environmental sampling tool(s) and assay device(s) with communication and computer processing systems onboard a typical FCS, JRP, or FIRRE combat casualty care UGV.

PHASE III DUAL USE APPLICATIONS:

1) Collaborate with topic author in transitioning the prototype system to operational testing under the Future Combat System (FCS), PM Force Protection FIRRE IPT, DOD JRP, the Personnel Recovery, Extraction, Survivability/Smart-Sensors (PRESS) or the Chemical, Biological, Radiological, and Nuclear (CBRN) Unmanned Ground Reconnaissance (CUGR) Advanced Concepts Technology Demonstrations (ACTD)

2) Transition the system to dual use casualty rescue applications with civilian police, fire, and medical first responders through ongoing US Army Medical Research and Materiel Command (USAMRMC) Telemedicine and Advanced Technology Research Center (TATRC) administered civilian first responder programs. Candidate dual-use civilian emergency first responder programs include the Center of Excellence for Remote and Medically Underserved Areas (CERMUSA) Robotic Emergency Medicine & Danger - Detection (REMED-D) program, the National Bioterrorism Civilian Medical Response Center (CiMeRC), and the Texas Training and Technology for Trauma and Training (T5) program.

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KEYWORDS: robot, bioagent, chemical, toxic gas, IED detection, medical evacuation, combat casualty care, JAUS; bio assay, chemical biological warfare agents, toxic gases, improvised explosive device, raman spectroscopy, sensors, optics

A06-T030

TITLE: Online Treatment of Subretinal Neovascular Membranes from Laser Eye Injury

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop and build an instrument that can be employed alone or coupled with existing scanning laser ophthalmoscopes for treatment of neovascular membranes that may develop in the setting of laser retinal injury or other disease processes (i.e. traumatic retinal holes, macular degeneration, diabetic retinopathy). This methodology would optimize directed-energy activation of photosensitizing dyes to eradicate these lesions.

DESCRIPTION: Laser retinal injury hazards are present in a variety of military settings. Incident reports abound from adversarial cockpit illumination to battlefield laser rangefinders and target designators as well as episodes of laser injury in government laboratories involved with high energy physics research or other scientific pursuits.(Stuck 1996; Zwick 1998) Subretinal neovascular membranes represent of the one of the most vision threatening complications of laser injury. Subretinal neovascular membranes also occur in age related macular degeneration and diabetic retinopathy. Currently, treatment of neovascular membranes involves the use of photodynamic therapy. Treatment involves patient rotation to separate stations in order to first diagnose then perform therapeutic membrane ablation. Advances in high speed digital imaging software and electro-optical technology may permit on-line treatment of these neovascular membranes utilizing a single instrument for both diagnosis and therapy. The present approach involves a cut and paste methodology, with eye care providers estimating lesion size from images generated by the initial patient evaluation. Therapy is then placed with a separate instrument in the general vicinity

of suspected retinal involvement. This frequently leads to missed portions of untreated neovascular membrane resulting in further vision deterioration and the need for repeat treatments. With high performance digital video technology it is possible to diagnose and identify these abnormal membranes in real-time, capture the precise location of affected retinal tissue, and, we propose, to utilize the same optical pathway to precisely apply therapeutic photodynamic therapy.

The successful completion of this project will involve the delivery of an advanced optoelectronic device that allows for the precise application of photodynamic therapy. The basic science behind photodynamic therapy utilizes light to activate a photosensitizing parenterally administered dye that interacts with abnormal blood vessels through the formation and release of oxidizing free radicals. As a consequence of this reaction, neovascular membranes are shut down. This reduces the extension of the original laser eye injury into surrounding unaffected retinal tissue. As mentioned in the objective section, current schemes for application of light to produce dye-activation often result in under-treatment and recurrence of the underlying neovascular membrane. Potential clinical application of this device also extends to uncommon wartime cases of PIC (punctate inner choroidopathy) associated with ocular histoplasmosis syndrome as well as conventional clinical treatment of age-related macular degeneration. From a basic research standpoint, one can compare the efficacy of hand delivery of light for dye activation to computer-assisted delivery of this therapy to improve treatment efficacy and visual outcomes.

PHASE I: Develop an interface with an existing scanning laser ophthalmoscope to process and capture images of retinal neovascular membranes to permit application of phototherapeutic laser energy to the affected tissue in real-time.

PHASE II: Develop a prototype unit that incorporates the concepts realized in phase one execution to allow user defined parameters for specific therapeutic laser window size, intensity, and wavelength.

PHASE III DUAL USE APPLICATIONS: The proposed system could be broadly applied to treatment of neovascular membranes that arise in the retina from a variety of other common medical conditions. Ocular histoplasmosis, retinal trauma, diabetic retinopathy, and age related macular degeneration may result in the formation of subretinal neovascular membranes that may benefit from treatment with this system.

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KEYWORDS: retinal laser injury, digital imagery, optical technology, computers, lasers, photodynamic therapy

A06-T031 TITLE: Military Specific Advancements in Prosthetic Limb Design and Performance

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop a concept and design a prosthetic component that can be used by military persons with upper or lower extremity limb loss. Conduct an engineering pass to incorporate identified necessary changes into the design followed by fabrication of manufacturing precursor devices for testing.

DESCRIPTION: Advancements in technology should allow increased utilization of prosthetic componentry for advanced skills specific to military activities, which include improvements in comfort, and stability during challenging environments incorporating high load or activity in altered terrain and temperatures, Therefore, this topic addresses the need for upper and lower extremity prosthetic limb performance and maintenance to support soldiers deciding to remain active duty.

A large number of injured soldiers recover to high functional levels with hopes of remaining on active duty in service to their country. However their recovery remains limited by available prosthetic technology. Basic soldiers' skills include many bilateral upper extremity tasks such as donning/doffing military gear, manipulating

computerized control panels and engaging various forms of weaponry. Task demands for the lower extremities include loaded marches for long distances over uneven terrain in various climates, climbing, running and rucksack maneuvers.

Specific areas of interest include:

1. Demand for more versatile, higher performance prosthetics with more lifelike external coverings for gloves and feet. According to Childress, very little technical progress has occurred in the area of upper extremity terminal ends. "... Gloves of the future must be better than current ones. They must be attractive, tough, stain resistant and affordable". [4]
2. Batteries, such as the typical nickel-cadmium cells, are a very common maintenance problem for prosthetic users. High prosthesis use hastens battery failure and few technological improvements have occurred in the past 20 years. The development of a new higher-power battery needs to also address load factors as different from the high energy batteries used for computers, telephones etc.
3. Newer technologies for wrist motion should provide movements in more directions for both above and below elbow amputees. Control schemes which perform coordinated function with less need for visual attention are also desirable.
4. Advancements are needed in the durability of harnessing and cabling systems along with new control mechanisms to meet high task demands of varied temperature and moisture environments.
5. Dynamic feet are needed with light-weight, multi-axial, foot-ankle coordinated componentry to increase stability on uneven outdoor terrain.
6. Improvements are needed for hand designs to provide independent digit movement or a conformable grip in which the fingers adapt and automatically take the shape of the object (additional grasp options such as spherical or lateral grip).
7. New designs for socket liners should provide adequate control of moisture and pressure using a thin, compliant barrier between the amputee's skin and the more rigid, weight bearing portions of the prosthetic socket.
8. Further advancements in microprocessor-controlled prosthetic components for finely tuned movement efficiency during walking/running and navigation of various terrains to include slopes and steps.

PHASE I: Design prosthetic limbs and componentry to allow improved performance in military specific activities of daily living in one of eight areas 1.) Materials and design to improve durability, 2.) Enhancement of power sources to provide extended periods of high-energy without increased load, 3.) Designs to enable multi-axial joint movements, 4.) Designs to enable comfort and proper fit, 5.) Advancements in hand design/technology to provide additional prehension options such as spherical or lateral grasp. 6.) Designs to decrease energy cost during military specific tasks. 7.) Advancements in Socket design and lining, and 8.) Advancements in microprocessor-controlled joint motion. Coordinate with applicable government and civilian health care organizations and facilities to access what would be required to execute Phase II.

PHASE II: Design and develop a prototype of the tool and test the prosthetic componentry within a suitable civilian/military clinical population. Demonstrate the prosthetic componentry as part of a performance study for military/civilian activities.

PHASE III DUAL USE APPLICATIONS: Extend the prosthetic componentry to multiple DOD, VA and civilian health care systems and incorporate local/regional user response grid preparation and training for executing integrated military/civilian medical responses to use of componentry in vocational and avocational pursuits for patient with traumatic limb loss.

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KEYWORDS: military tasks, amputee, prosthesis, hand, socket liners, multiaxial joint, microprocessor-controlled, upper extremity, lower extremity, energy cost, gloves, cable systems, battery power, harness systems

A06-T032 **TITLE:** High-throughput Direct Structural Screening for Drug Lead Compounds

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The overarching goal of this topic is to combine recent developments in high-throughput structure determination and protein::ligand interaction mapping to rapidly screen small molecule compound libraries for novel drug leads targeting malaria, severe and complicated malaria, and multi-drug resistant malaria. Once developed, this technology can be used to develop drug leads against any infectious disease, or other protein-targeted drug discovery program.

DESCRIPTION: U.S. Government personnel deployed in tropical and neotropical regions continue to be at risk for developing malaria. Drug resistant malaria parasites are becoming more common in these areas, increasing the risk of American personnel developing serious, life-threatening disease. Cross resistance between drugs is becoming much more common. Due to the emergence of drug resistance, derivatives of known anti-malarial drug classes are not long term solutions. Faced with the realities of the malaria threat, novel, unbiased technologies are required to prime the drug discovery programs. The development of an integrated NMR and x-ray crystallographic direct binding drug lead system will leverage existing knowledge of Plasmodium enzymes and provide novel classes of lead compounds while developing innovative screening technology.

In current practice, protein structural information is used very late in the drug development cycle, generally in the drug optimization stage. The use of structural studies so late in the development cycle means that valuable time, generally measured in years, has been expended on a set of lead compounds. Discovering a poor lead compound choice at the structural characterization step is catastrophic. Many drug discovery efforts collapse under the weight of poor early lead compound decisions. Direct screening of small molecule compound libraries (fragment libraries) with NMR followed by x-ray crystallography will avoid this failure scenario.

Development and maturation of direct screening technologies will provide not only collections of small molecule compounds that bind to a protein target, but provide details of the interaction. With direct x-ray crystallographic screening, the complete binding site on the protein and specific atomic interactions with the compound will be characterized. Parallel use of NMR screening will identify key interactions between the lead compounds and the protein without the overhead of complete structural assignment or having to produce protein crystals. Pre-screening the library with NMR followed by x-ray crystallographic screening of the NMR hits has the potential to allow large numbers of compounds to be screened with only the more promising passing on to the more time intensive crystallographic screening step. There is no a priori preference for x-ray over NMR methods to implement the direct screening concept. Each applicant should suggest the method or combination of methods that, in their scientific judgment, will more effectively achieve the through put goals, and allow the method to be most generally applied to the largest number of potential drug discovery targets.

PHASE I: Conduct a proof-of-concept study that can demonstrate the ability to detect the interactions of a known dihydrofolate reductase inhibitor with wild-type and/or quadruple mutant *P. falciparum* DHFR-TS. A proof-of-concept software module automating at least one step of the NMR or x-ray data collection, processing, or analysis should be developed to demonstrate the ability to handle the software engineering requirements of developing the complete direct screening technology package. In lieu of DHFR-TS, the incumbent may select a structurally well

characterized protein target from a “neglected” tropical disease (e.g. malaria, leishmania, chagas disease, dengue fever, or West Nile virus) or a CDC Category B or C organism.

PHASE II: Develop moderate to high-throughput direct structural screening of fragment libraries using NMR and/or x-ray crystallographic methods. Minimum throughput should be screening 50 to 100 fragments/week against a single protein target. The Phase II target may be selected from the list below or may be a well characterized protein target from a “neglected” tropical disease (e.g. malaria, leishmania, chagas disease, dengue fever, or West Nile virus) or a CDC Category B or C organism.

Possible Phase II Targets: Plasmodium falciparum (Pf)DHFR-TS quadruple mutant (GI#30749353); PfKASIII (PfB0505c); PfHsp90 amino terminal ATP-binding module (Pf11_0188); Pfmrk; PfPK5, PfPK6, Pf shikimate kinase; Pf dihydroorotase (PfDHOase); Pf chorismate synthase (MAL6P1.199); Amino terminal ATP-binding domain of a vertebrate Hsp90 (e.g. human EMBL AY359878, chicken SWISS Prot P11501).

PHASE III DUAL USE APPLICATIONS: The development of an integrated technology platform to directly screen small molecule compound libraries would aid all investigators searching for drug leads. Civilian and military drug discovery efforts would benefit from an integrated solution to this challenging set of biophysical methods. In particular, development of this technology would enable small- and medium-sized pharmaceutical companies; biotechnology start-up companies, and university funded initiatives to use direct screening in their drug discovery programs. This technology would also enhance drug discovery and vaccine development for numerous infectious diseases (e.g. leishmania, dengue fever, typhoid fever, and hanta virus).

POTENTIAL APPLICANTS: Ideal applicants for this STTR program would be Academic Structural Biology Consortia with access to synchrotron beam lines (formal or informal collaborations with DOE Collaborative Access Teams); Teams of academic investigators from Universities, Medical Schools, or Schools of Pharmacy; and Non-profit research foundations with established structural biology capabilities

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KEYWORDS: drug discovery, x-ray crystallography, structural screening, NMR, automation, high-throughput structure determination, TNOE, common platform drug discovery system

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Sound propagation through the human skull will be modeled. The model will include parameters such as skull dimensions, type of head covering, and noise environment that can be input in order to predict bone conduction communication system effectiveness for individuals in various circumstances. The model will be used to improve bone conduction communication systems to a level where they will be able to be used in military environments.

DESCRIPTION: The perception of sound through bone conduction involves the transmission of sound to the inner ear through the bones of the skull. Bone conduction offers several potential advantages over air conduction (normal hearing through the ears) as a means of communication in military environments. For example, the ears do not have to be covered which allows the surrounding acoustic environment to be monitored, and bone conduction communication systems are less sensitive to ambient noise and may be a better alternative to noise-canceling devices in high noise environments. Several commercial bone conduction microphones and speakers currently are available for civilian applications, but the technology is not yet mature enough to provide high fidelity devices required for military operations across a variety of environments. In particular, speech intelligibility is not very good with the devices (e.g., Acker, Houtsma, and Ahroon, 2005). The sound quality and intelligibility of speech are dependent on the technical parameters of the bone conduction transducers and the placement of the transducer on the head of the communicating person. It is believed that signals transmitted to or received from specific locations on the head will have better speech intelligibility than signals to and from other locations. Fundamental research assessing the nature of vibration and acoustic characteristics of the human skull is necessary in order to improve bone-conduction communication systems.

Computer models that capture the behavior of the skull and vocal tract are needed to predict the regions on the skull most sensitive to mechanisms of both transmission and reception of sound. This research will fill an important gap in our knowledge regarding head vibration patterns and will be used to predict how well individuals will be able to use bone conduction systems based on their personal anthropomorphic characteristics.

PHASE I: Determine if a model of the acoustic properties of the human head can predict speech intelligibility using bone conduction communication systems. Develop a model that will capture skull vibration patterns in response to external, localized vibration input (i.e., a bone conduction speaker). The vibration input will include a frequency range from about 500 to 6000 Hz at several different intensity levels. The model will provide predictions for ideal and non-ideal bone conduction speaker placement. Using stimuli recorded from an acoustic microphone, the model's predictions will be tested by measuring speech intelligibility (e.g., the Diagnostic Rhyme Test as specified in ANSI S3.2-1989, R1999) for the predicted ideal speaker placements. Speech intelligibility also will be measured for a non-ideal speaker location. The model's adequacy will be determined by the degree to which the model predicts speech intelligibility based on the location of the speaker on the skull (i.e., the predicted ideal location results in high degrees of speech intelligibility and the non-ideal location results in poor speech intelligibility). Investigators must obtain IRB approval from the local institution and from the U.S. Army Medical Research and Material Command for all human speech intelligibility testing.

PHASE II: Include the vocal tract as a parameter in the model developed in Phase I. Map skull vibration patterns in response to vocal tract vibrations. Determine ideal bone conduction microphone placement. Select ideal and non-ideal locations from which to record speech stimuli. Evaluate speech intelligibility for the recorded stimuli. The model's adequacy will be determined as in Phase I, except listeners will use regular acoustic headphones to listen to the bone conduction microphone stimuli. (In Phase I, listeners will use bone conduction speakers to listen to stimuli recorded with acoustic microphones.) Finally, evaluate the effect of skull anthropomorphics, helmet type (to be provided), and environmental noise on skull vibration patterns. Incorporate as variables to be input by the user of the model. Investigators must obtain IRB approval from the local institution and from the U.S. Army Medical Research and Material Command for all human speech intelligibility testing.

Develop a software program that will allow the user to input variables important to bone conduction effectiveness. The output will include some metric that will indicate if bone conduction speakers/microphones should be used by a

particular individual in a particular environment. Evaluation will include assessing how well the output predicts speech intelligibility for the given person/environment.

PHASE III: Market the software to companies that manufacture bone conduction communication systems. Predicting effectiveness for an individual and improving bone conduction transducers will allow the systems to be used effectively in a variety of civilian and military environments.

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KEYWORDS: Sound propagation, noise, bone conduction, microphone, speaker, speech intelligibility, computer model

A06-T034 TITLE: Neurotoxicity Associated with Mefloquine, an Anti-Malarial Drug

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: To define the biological mechanisms of mefloquine neurotoxicity, identify genetic and other predispositions to mefloquine neurotoxicity, and identify whether mefloquine neurotoxicity may extend to other anti-malarials as a class effect.

DESCRIPTION: There are estimated to be 350-500 million clinical cases of malaria and at least a million deaths annually (13). This disease represents a major threat of force reduction for forces deployed to tropical and subtropical regions and is endemic in AORs of all five of the major U.S. commands. Of 290 U.S. Marines deployed to Liberia in 2003 for less than two weeks, 80 developed malaria and five required intensive care, largely due to medication noncompliance. This experience again demonstrated that effective and safe anti-malarial prophylaxis and treatment is not only important in regards to the worldwide burden of disease, but to the specific force protection of deployed U.S. forces.

Currently, mefloquine and chloroquine are the only anti-malarial drugs with a long enough half-life to allow once per week dosing (5). This dosing schedule and its effectiveness against chloroquine-resistant malaria makes it very valuable for deployed forces who may operate under conditions that undermine daily dosing. Unfortunately, as many as 25% of individuals taking mefloquine at prophylactic doses (250 mg per week) and 70% of those taking it at treatment doses (1250 mg over 24 hours) experience neurological or psychiatric adverse effects. While most of these are minor (dizziness, anxiety, nightmares, reduced sleep), serious adverse effects such as psychosis also occur (6-12). The fact that only certain individuals appear to be adversely affected points to a genetic mechanism, possibly a single polynucleotide polymorphism (SNP) that is yet to be identified.

Recent work using a rodent model has demonstrated histologically evident damage in the brainstem of rats given mefloquine that appears to be dose-dependent (2). Neurological and behavioral abnormalities were also observed with likely correlates to the common adverse effects observed in humans (1,2). This work along with previous investigations that include retrospective studies of the effects in humans, form a growing body of evidence of a biological basis of mefloquine neurotoxicity (6-12). The accumulation of mefloquine within the central nervous system is well documented and while several possible targets leading to toxicity have been identified, the exact mechanism or mechanisms leading to toxicity remains to be defined (4). Whether this toxicity is related to that observed with other anti-malarials is also unclear (3). If a class effect exists, it is critical that this be elucidated.

PHASE I: As a proof of concept, initial studies will identify the cellular and subcellular mechanisms of neurotoxicity. This will extend beyond work done at WRAIR and other academic institutions that have identified several possible targets leading to toxicity to include the regulation of neuronal cellular calcium, adenosine 2A

receptors, and p-glycoproteins. The identification of such specific targets (proteins) will allow investigators to “work backwards” to identify the associated RNA and DNA sequences, likely employing microarray analysis.

PHASE II: Building on Phase I results, these studies will identify the genetic profile, including specific SNPs, which predicts susceptibility to mefloquine-induced neurotoxicity. This will likely involve identifying prior cases of mefloquine toxicity. By identifying a genetic marker for neurotoxic susceptibility, a prototype genetic test can then be developed. Such a test will allow commanders in the future to identify who is at risk for the development of adverse effects. This will allow the safe administration of this valuable drug to the majority of service members while protecting the few with susceptibility via the use of alternative medications.

PHASE III DUAL USE APPLICATIONS: Using commercial partners, the prototype genetic test can be developed into a commercially available test. The reliability of its predictive value can be ascertained in prospective studies. Given the large burden of malaria worldwide and the common use of this medication, a commercial market for this “safety” test is likely.

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KEYWORDS: mefloquine, toxicity, neurotoxicity, malaria, neurological, anti-malarial

A06-T035 **TITLE:** Models to Predict G6PD-associated Hemolytic Toxicity of Antimalarial Drugs

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The objective of the topic is to develop and validate models to estimate risk for antimalarial drugs in G6PD-deficient persons. An in vitro model is needed in drug discovery to estimate risk, and an animal model is needed to accurately estimate the therapeutic index early drug development.

DESCRIPTION: Malaria is a major infectious disease threat to U.S. forces deployed worldwide and can rapidly incapacitate large numbers of personnel. New drugs to prevent and treat this disease are a priority for the US military.

Glucose-6-Phosphate dehydrogenase (G6PD) deficiency is the most common enzymopathy, affecting 400 million people worldwide. It is prevalent in malaria-endemic areas and drugs active against malaria (e.g. primaquine, tafenoquine, methylene blue) have a propensity to cause hemolysis in G6PD-deficient individuals. A “clear-cut” dose response for primaquine-induced hemolysis is published. Epidemiologic data suggest 15 mg primaquine per day does not cause substantial mortality despite widespread use without screening. The risk of higher doses is unknown, but is likely higher. Available tests are 100% sensitive for substantially affected individuals. However, laboratory errors will occur, probably at a rate relative to the level of health care available. Many new antimalarial drugs and new 8-aminoquinolines are in development. For all, risk of toxicity in G6PD-deficiency remains poorly defined. In vitro, in vivo, and in vivo-in vitro models to better define risk drug development are needed.

Tafenoquine is a new drug in the same class as primaquine, but having a 3-week half life. Its risk is only known from two G6PD-deficient women who were accidentally dosed. Tafenoquine’s risk must be better understood in animal and human models where a therapeutic index relative to primaquine can be estimated.

A test to eliminate candidate drugs in early development that have hemolytic activity in G6PD-deficiency is needed. No clear structure-toxicity relationship has been established. Several in vitro models have been previously developed for this purpose, however, all of these models had at least one significant limitation. One of the major contributors to the poor predictive ability of initial models is the fact that metabolism of the parent drug is often required for hemolytic activity. Subsequent models attempted to compensate for this requirement by incubating the drug with G6PD-deficient (A-) [Gd(A-)] erythrocytes in the presence of mouse or rat liver microsomes in order to allow metabolism to occur. For instance, Bloom, et al. were able to correctly predict 75% of known hemolytic and 100% of non-hemolytic compounds using mouse liver microsomes and reduced glutathione (GSH) as a marker of hemolysis. While this was a dramatic improvement over previous observations, several drugs gave false-negative results in this model. This model is also based on several assumptions: that metabolism by mouse liver microsomes is representative of human Phase I metabolism, that hemolysis in Gd(A-) RBCs is representative of hemolysis for all G6PD-deficient individuals, and that GSH alone is a predictive marker of hemolysis. Additionally, the evidence that the hemolytic compounds identified are truly hemolytic was not clearly presented. Many compounds on the list of “drugs to be avoided in G6PD deficiency” have very limited evidence that they are clinically problematic. Lastly, a dose response was not defined for the hemolytic activity. In fact, in an in vitro model based on Bloom’s work, Bashan, et al. found that only four of seven agents known to be hemolytic caused a reduction in GSH in Gd(med-) cells.

PHASE I: Identify appropriate methods and innovative technologies to ensure accurate prediction of G6PD hemolytic risk in either a screening method (probably in vitro), for a therapeutic index (probably in vivo), or both. The following must be presented at the end of Phase I: feasibility assessment of the method to achieve a validated sensitive (>95%) and specific (> 95%) model at the end of Phase II, pilot data supporting the feasibility assessment, detailed criteria for assessing sensitivity and specificity, detailed criteria for validation, and detailed validation plan. Collaboration with institutions with G6PD and malaria-related clinical trials experience is strongly encouraged.

PHASE II: Fully validate model(s) following plan developed in Phase I. Validation must be to US Food and Drug Administration Standards and must be published in the scientific literature.

PHASE III DUAL USE APPLICATIONS: Implement models to ensure commercial viability. Dual Use: Concern about G6PD-deficiency is a common problem in drug development. If predictive models were available, wide spread screening would likely be used by pharmaceutical companies, non-profit organizations, and others doing drug development.

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KEYWORDS: glucose-6-phosphate dehydrogenase deficiency, G6PD, malaria, plasmodium vivax, model, validated, diagnosis, diagnostic, antimalarial, drug development, hemolytic, hemolysis, animal model, in vitro model, laboratory, life-saving, military, soldier, malaria