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 2005 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, 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 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 2005 Topic Descriptions

A05-T001 TITLE: Distributed Interactive Training for Battle Command Embedded Training

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a methodology and development tools to support the rapid development, evaluation, integration, management, and execution of reusable, adaptable, and scalable vignette-based embedded battlefield decision-making training exercises that will provide a base for developing the next generation of embedded training systems for deployed units in the Future Force. The goal is to provide the Army with a set of realistic tools for implementing an effective embedded training system for the development of tactical skills across various levels of command.

DESCRIPTION: The embedded training concept is the centerpiece of Future Combat System of Systems (FCS) training and represents one of its key performance parameters. The FCS system will have an embedded tactical simulation capability and a library of training support packages (TSPs) to facilitate collective tactical training exercises. Embedded simulation, along with the library of TSPs can replicate the capability available today in fixed-site simulations such as the Close Combat Tactical Trainer while allowing for ready deployment of the training capability. While simulation-based exercises bring an excellent practice capability and embedded simulation makes that capability deployable, advanced Interactive Multimedia instruction (IMI) may be more readily applied to training deployed Soldiers. The conclusion is also supported by FCS training developers; their vision for, and use of, embedded training systems suggest that IMI will be the most utilized component of the embedded simulation system.

For deployed units, the embedded training system must focus on key activities that are specific requirements of the operation, for example operating in a chemically contaminated environment and using the newly fielded equipment. Additional needs are individual and collective training relevant to the environment and to the mission with which the unit is being deployed (language, culture, terrain, weather). Significant training will be directed to mission-specific tactics, techniques, and procedures (all of which will be rapidly changing as the enemy adapts) and to responding appropriately to enemy tactics, (e.g., improvised explosive devices) and in particular to emerging threat tactics that cannot be fully anticipated and that evolve as operations continue. Undoubtedly, practice exercises that accompany the training ought to be set in the authentic conditions of the deployed unit with regard to key features such as mission, terrain, organization, and enemy tactics.

Each deployment is unique and entails a different set of behavioral responses, a different mindset that is perhaps expressed most clearly in how the rules of engagement are applied. Training must be tailored to a specific training need to behaviorally prepare Soldiers for specific deployment environments, allow the Army to capitalize on the flexibility of the individual Soldier. It is that flexibility that allows the force to adapt itself so greatly to specific mission requirements that would be very difficult to explicitly codify. These deployed training requirements may more easily be accomplished by more advanced methods of IMI.

Deployed Soldiers need training to practice, and rehearse tasks specifically directed at upcoming missions. Simulation-based live, virtual, and constructive simulation does not easily lend itself to the rapid development of training in these conditions. Interactive multimedia instruction can be developed more quickly than simulation-based collective exercises, but it also does not fully satisfy the requirement. Traditional IMI primarily accomplishes knowledge acquisition, rather than training behaviors. What is needed is a flexible form of IMI that can focus on very specific training needs, be readily tailorable, updated quickly, and is effective in turning knowledge into action via training.

The U.S. Army's experience with the Think Like A Commander (TLAC) training method may provide a solution for the deployed training requirements described above. The TLAC methodology applies deliberate practice training concepts to train tactical thinking skills and allows students to model their thinking, understanding, plans, visualizations, and decisions after expert thinking patterns. The training method involves the presentation of

cognitive drills - multimedia scenario-based situations - and structured questioning to elicit and assess an individual's mental models and thought habits.

While the TLAC method may be appropriate, methods for implementing such an approach and vignette development tools are needed to support the rapid development, evaluation, integration, management, and execution of vignette-based embedded training exercises within an embedded training/distance learning environment. In particular, such rapid training development tools need to leverage the operational capabilities available to deployed units including mission and terrain databases and analytic capability.

PHASE I: Phase I activities will result in proof-of-concept approach and techniques for the development of methods and tools to support the rapid creation and implementation of vignette-based battle command training for deployed units, a top level architecture for the development of such a system, the identification of required processes and tools for the implementation and management of training, and an initial concept demonstration prototype highlighting the proposed approach.

PHASE II: Build on the design and architecture from Phase I to design and develop a functional prototype system, validate the feasibility for implementation, and outline required Army processes for managing the training system and approach. Phase II activities should also result in fully integrated vignette development tools and processes to allow for the efficient and timely development of new training exercises - including the development of training vignettes with information supplied by a live operational system. Phase II efforts should address distributed performance evaluation, feedback, and coaching for deployed units.

PHASE III: Develop methods to scale the prototype systems developed in Phase II to support large numbers of concurrent training activities in a distributed environment across the full range of battle command training. It is also expected that the SBIR contractor seek to commercialize the SBIR research/development products. Commercialization of the technologies enabled via successful PHASE I/PHASE II efforts should reflect product development that is marketable for applications related to industrial and commercial training needs. The SBIR contractor should identify a commercialization area of choice and present a marketing place to support their commercialization effort.

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KEYWORDS: Battle Command, Training, Decision Making, Embedded Training, Distributed Training, Deployed Training, Exercise vignette Development, Performance Coaching

A05-T002 TITLE: Distributed Heterogenous Large Data Visualization of Physics Based Simulations

TECHNOLOGY AREAS: Chemical/Bio Defense, Information Systems

OBJECTIVE: Develop a system that is capable of generating interactive visualizations of enormous datasets that result from physics based simulations on US DoD High Performance Computing facilities. The parallel and scalable visualization system should be both an end user application, and a toolkit which enables the development of custom visualization tools. Using scalable rendering techniques, the system should operate on the datasets as they reside on the HPC platforms and display the results to a networked desktop machine and multi-display systems with modest memory resources.

DESCRIPTION: Many important DoD Key Technology Areas, such as Weapons, Materials, Chemical/Biological Defense, and Sensors rely on High Performance Computing physics based simulations. These simulations regularly generate terabytes of data that needs to be analyzed via scientific visualization techniques. Moving that data to a remote location for visualization is impractical if not impossible. While techniques such as feature extraction and sub-sampling can be useful, it is commonly necessary for important visualization algorithms to operate on the entire dataset. Performing these algorithms on the HPC platform itself is a natural step in this process. Over the past several years however, the tremendous increase in the power of commodity graphics cards has outpaced the native, integrated graphics sub-systems available on HPC platforms. Groups of inexpensive commodity systems are increasingly used to construct multi-display systems. By combining the output of multiple displays via rear-projection screens, scalable display resolutions can be achieved.

The US DoD would benefit from a system that could visualize structured and unstructured grid datasets using polygon-based and volume visualization techniques using HPC platforms for the algorithms and single or multiple commodity based systems for the display and interaction. Structured grid dataset size can reach the multi-billion cell level while unstructured grid datasets are typically an order of magnitude smaller. Displays can be a single desktop display, a multi-display co-planar system (DisplayWalls) or a multi-display multi-planar display (CAVE/RAVE). The system would need a graphical user interface as well as a scripting interface for custom visualizations.

While a single visualization application may be sufficient for many simulations, there will always be a need for customization. Therefore, the system should be capable of being utilized from a custom client written in C++ or the Python scripting language. This will allow both the production visualization environment and the customizable tools to be based on the same scalable/parallel subsystems.

PHASE I: This portion of the effort will consist of identifying major visualization algorithms that will be included in the system and identifying the necessary software subsystems necessary to accomplish efficient client-server visualization between HPC systems and multi-display clients.

PHASE II: Using the results from Phase I, the effort will be to build a robust system and interface to handle a wide variety of dataset topologies. User and Developer documentation will be developed at this time.

PHASE III: Final phase of the effort involves commercialization of this product which will be of interest to a wide variety of physics based simulation visualization users, namely, automobile industry, chemical and drug industry, Govt. laboratories including DoD and DOE. Software for visualization of physics based simulations is an active market. Some examples include, EnSight from Computational Engineering International (CEI), is one of the widely used commercially available product, and domain specific software FieldView from Intelligent Light which is a commercially available visualization product for computational fluid dynamics. Most of the commercial visualization software's were in existence for over ten years or more. To take advantage of new computing systems, computing languages, and new software applications a more modern and flexible software is needed. The software

developed in Phase III of this effort will benefit from a more modern software design and more flexible interface for customized visualization which can address a wide class of applications (Example: Weapons development, automobile crash analysis, Vaccine and drug design using computational biology/chemistry, etc.) taking advantage of emerging computing systems. It would therefore fill a needed void in commercially available software and be of interest to many users of physics based simulations both in the Govt. and industry.

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3) Python Home Page, http://www.python.org current as of September 9, 2004
4) Kenneth Moreland and David Thompson. "From Cluster to Wall", In Proceedings of IEEE 2003 Symposium on Parallel and Large-Data Visualization and Graphics, pp. 25–31, October 2003.

KEYWORDS: Interactive Visualizations, simulations, High Performance Computing, parallel visualization, scalable visualization, multi-display systems

A05-T003 TITLE: Physical Model for Gelled Propellants

TECHNOLOGY AREAS:

OBJECTIVE: Develop a model to describe the physical properties of gelled propellants.

DESCRIPTION: Gelled propellants have significant safety and handling advantages over liquid propellants due to their physical properties while maintaining the ability of liquids to throttle and turn on anD off. An understanding of the inter-molecular forces that produce these properties will provide the gel propellant developer tools to more efficiently synthesize new propellant ingredients and to tailor formulations for optimum performance for specific applications. This topic will develop a model for gel propellants that will accurately predict yield stress, syneresis, the shear thinning behavior, density, vapor pressure, surface tension in air and within metal manifolds, and aging behavior such as the loss of yield point, settling of solid additives, and the increase in syneresis with time. Syneresis is defined as the percentage of liquid that exudes from the gel after being centrifuged at 500 g for 30 minutes. Inputs to this model will be physical and chemical properties of the liquid phase, the gellant, surfactants or crosslinkers, and/or a solid performance enhancer. The model will be applied to both fuel and oxidizer gels.

PHASE I: Identify the key parameters that will be needed to develop a gel propellant model and determine how these have been used in previous chemical models. Develop an outline of the model and a rudimentary conceptual model. Use the properties of the carbon-loaded MonoMethyl Hydrazine (MMH) fuel gel and Inhibited Red Fuming Nitric Acid (IRFNA) oxidizer gel used by the FMTI program to determine how close the predictions of the conceptual model are to the propellant properties.

PHASE II: A detailed model will be developed based on the conceptual model. The detailed model will be validated by the propellants from Phase I, the MICOM fuel gel that includes 60% aluminum as a solid performance enhancing additive, the MICOM oxidizer gel that includes 35% lithium nitrate as a solid performance enhancing additive, and a fumed silica-gelled MMH fuel formulation. The model will be tested by predicting the physical properties of a novel fuel and oxidizer gel that has never been formulated previously, to make the gels, and to compare their properties to the predicted value. It is assumed that there will be some physical property test method development in Phase II for both the propellant ingredients and formulations.

PHASE III DUAL-USE APPLICATIONS: After a successful Phase II program, the small business has two options to commercialize the technology: to sell/lease the model or to sell their services to those companies who do not want to operate the model themselves. In either case, the small business would modify the model to apply to the user's specific application. There are three industries that would be interested in the model. The model is being developed to more effectively and efficiently improve gel propellant formulations, therefore, both DoD and NASA propulsion applications would be ideal marketing targets. Gel bi-propulsion systems can be used by NASA for launch vehicles,

spacecraft, and satellites. They are applicable for simple boosters as well as when variable thrust is required. The increased safety of gels over hypergolic liquids decreases the hazards of manned space flights and ground operations. A single engine could be used for changing from low to high earth orbit as well as precision positioning of the satellite for operational purposes, such as detecting leaking dams or mapping crop infestations. DoD is interested in gel propulsion because of thrust management advantages and/or increased safety of gelled propellants. Both government organizations and liquid propulsion houses would be potential customers. The pharmaceutical industry is interested in churn-type mixers developed under the SBIR program. They would be interested in using the model to develop a gel with optimized properties specific to the drug's medical application. The food and cosmetic industries would be interested in the model to minimize manufacturing costs of the myriad of products such as mayonnaise, ketchup, toothpaste, and deodorant.

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KEYWORDS: fuel gel, oxidizer gel, yield stress, syneresis, density, surface tension, theology, accelerated aging, monomethyl hydrazine, inhibited red fuming nitric acid, physical properties, inter-molecular forces, modeling

A05-T004 TITLE: Hybrid Textile-Based Multi-Layered Flexible System for Penetration Resistance

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: To develop innovative methodologies and techniques that use hybrid (combinations of different fibers) 3D woven fabric in a multi-layered material system to provide both flexibility and penetration resistance. This project should utilize the ability of textile-based fabrication methods to incorporate different fiber types in specified locations and could include other hard materials in such a way that flexibility is not degraded. Approaches should be developed to optimize the 3D woven fiber architectures, identify the best material combinations and system topology to mitigate penetration. Experiments and computational tools should be used to determine overall strength and response of these systems under impact loading conditions for the development of reliable design guidelines for new and significantly improved high strength and low-weight applications, such as body armor, structural systems, and mechanical components. This project seeks to develop flexible body armor that weighs less than 1 lb/ft^2 and has the ability to protect against a wide range of fragment masses and velocities that result from blast loading and improvised explosive devices.

DESCRIPTION: Three-dimensional woven, braided or stitched fibrous assemblies are textile architectures having fibers oriented so that both the in-plane and transverse tows are interlocked to form an integrated structure that has a unit cell with comparable dimensions in the all three orthogonal directions. This integrated architecture provides improved stiffness and strength in the transverse direction and impedes the separation of in-plane layers in comparison to traditional two-dimensional fabrics. Recent automated manufacturing techniques have substantially reduced costs and significantly improved the potential for large-scale production. Optimal orientations, fiber combinations and distributions of yarns have yet to be fully developed and perfected for 3D fabrics subjected to impact loading conditions. Current body armor rely ceramic plates to defeat penetrators. The rigidity and brittleness of these materials limit their use to only the torso of the war fighter. In addition, over time, environmental degradation and inadvertent drops damage the ceramic and render it ineffective. So that ample movement is still possible, innovative concepts that combine hybrid 3D fabrics with other materials such as ceramic and possible new nanoscale materials are needed. Optimal combinations of these materials need to be determined along with new methodologies to ascertain how to utilize inherent mechanisms (friction, microcracking, fiberbreakage, fiber bridging, etc…) of these systems for energy dissipation and strengthening.

PHASE I: Establish design criteria (fragment sizes and velocities) based on blast modeling and computations. Demonstrate the feasibility of tailored 3D textile-based flexible body armor systems by using dynamic experiments and computational tools to determine response as a function of fiber types, fiber orientations, distributions, and system topology. These interrelated tools should be used in conjunction with cost-effective processing techniques to determine optimal armor system. Comparisons with 2D woven architectures should be undertaken, as a benchmark, to assess performance and durability, and to delineate advantages of the 3D hybrid systems. Prototype designs that can be efficiently processed fabricated, and tailored to resist high velocity impact and penetration should be developed.

PHASE II: Prototype designs from Phase I should be specialized for a specific application, such as body armor protective vests, helmets, or extremity protection, which can be efficiently manufactured. Experiments and computational tools should be used to assess and evaluate the durability and performance of these designs to realistic threats and dynamic loading conditions. Reliable guidelines should be then be developed for the design, processing, and fabrication of these prototypes for batch production.

PHASE III DUAL USE COMMERCIALIZATION: There are a large number of dual use applications. 3D woven textile-base armor systems can be used for high strength, lightweight, and damage tolerant applications, such as body armor (torso, head, extremities), bomb containment devices, and as structural elements and components in military and commercial vehicles, off shore marine platforms, shelters, automotive and marine components, and hardened structures.

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KEYWORDS: Advanced fibers, textile, hybrid composite, armor, body armor, 3D textile composite architectures, impact and penetration, fiber volume fractions, 3D fabrics, performs, energy dissipation mechanisms

A05-T005 TITLE: Compact Formic Acid Fuel Cells

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes

OBJECTIVE: Develop a compact, soldier-portable fuel cell power system that uses cartridge-delivered formic acid as the fuel. The power system must deliver 20 W at 12 V for 72 hours with a system energy density of 600 Wh/kg or greater.

DESCRIPTION: The soldier requires compact (lightweight and small volume) portable power systems. A proton exchange membrane (PEM) fuel cell (FC) system is a candidate power source to fill this need. At a theoretical energy density of 33,000 Wh/kg, hydrogen is seemingly the choice as fuel for a fuel cell but its supply is problematical: hydrocarbon liquid fuels may be reformed to supply hydrogen at the expense of system complexity and a system weight/volume penalty, and presently available metal hydrides store hydrogen at too low loading for practical use. Direct electrochemical oxidation of methanol (6,100 Wh/kg) in a fuel cell (DMFC) is an alternative approach, and there has been considerable investment and investigation in developing a compact DMFC system for military use (e.g., 1). Nevertheless, significant technological challenges remain, for example: methanol diffusion across the PEM lowers fuel utilization and cell voltage, which limits the concentration of methanol to less than 1 M with state-of-art PEMs; high loading of precious metal electrocatalysts is needed; and, balance-of-plant components comprise a large fraction of system volume and weight. There has been recent university-led interest in direct formic acid fuel cells (DFAFC) for sub-watt power systems (2). Even though the theoretical energy density of formic acid (1,700 Wh/kg) is 30% that of methanol, there are potential advantages that it may offer, for example: formic acid is relatively benign (it is used as a food additive); 65 wt % formic acid solution in water has a freezing point of -50 C; lower cost catalysts may be used to electrooxidize formic acid (3); and, concentrations as high as 20

M have been used since crossover of the fuel through the polymer electrolyte in a PEM fuel cell is low in comparison to methanol (4). Because of tolerance to concentrated formic acid as feed, it might be expected that balance-of-plant issues in a DFAFC system are less of a concern in comparison to a DMFC system and potentially lead to a simpler and competitive power system. In this regard, a completely passive 1.5-W DFAFC has been reported for use in a cell phone (5). It remains undetermined, however, if a DFAFC can form the basis of a 20-W compact power system for the soldier. Several questions that can be posed include: Can a totally passive DFAFC system be constructed to meet a 20 W demand? If needed, are balance-of-plant components required in low number and complexity to compensate for the lower energy density of formic acid in comparison to methanol? Can low loadings (or low-cost loadings) of electrocatalysts (in comparison to a DMFC) meet power demand and potentially result in a cost-competitive power system? These and other issues in a DFAFC power system for the soldier remain unresolved and are to be addressed by this topic.

PHASE I: In a polymer electrolyte membrane cell, evaluate single-cell performance of an air-fed formic acid fuel cell as a function of acid concentration, electrocatalyst and loading in membrane-electrode assembly, temperature, etc. Based upon best conditions found, construct and report upon polarization behavior of an air-fed 3-5 W DFAC cell stack. Using these stack results as the basis, develop a conceptual design of a DFAFC power system producing 20 W at 12 V for 72 hours. Report weight and volume of all system components; include projected system energy density (on mass and volume basis).

PHASE II: Design, construct, and evaluate a direct oxidation formic acid fuel cell power system that produces 20 W at 12 V for 72 hours. Fuel is to be delivered through a cartridge feed to enable quick change without power interruption. Capacity of single cartridge is not to be less than 480 Wh of delivered energy. Deliver power system and fuel cartridge units to Army for test and evaluation.

PHASE III DUAL USE APPLICATIONS: Developments in fuel cells 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: Formic acid; fuel cell; soldier power; compact power

A05-T006 TITLE: Effective Malware Detection Through Static Analysis

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The objective of this STTR is to research and develop a high confidence malicious code detection system.

DESCRIPTION: Malicious code (Malware) detection has been received lots of attention lately. There have been numerous recent computer virus outbreaks that caused severe damages ranging from financial losses to interrupted services. The need to safeguard computing devices from malicious code invasion is urgent and critical. Unfortunately, a recent study indicates that existing commercial anti-virus software has a high failure rate in dealing with sophisticated malicious code that uses advanced techniques to disguise itself [1]. This STTR aims to research and develop a high confidence malicious code detection system.

Malicious code detection employs automatic analysis techniques to determine whether a piece of computer code is benign (normal) or malicious. There have been active researches in the area of malicious code detection. Both static analysis (that analyze and verify a code before it runs) and runtime checking have been proposed and studied. The static analysis analyzes and verifies a code before it runs. Static analysis has been used to solve many security

problems [2-9] ranging from buffer overflow detection, to race conditions, and to general control flow based security properties. The detection involves a series of analysis and verification steps performed on the computer code in question, before such code is allowed to be imported and to run on the targeted system. On the other hand, runtime checking monitors the behaviors of a computer code and prevents the code from performing aberrant behaviors such as illegal memory access or abnormal system calls [10-13].

An accurate and powerful malicious detection system needs to prevent malicious code from infiltrating the target system. If the detection system fails to detect an incoming malicious code and allows such code to run on the targeted system, it is almost certain that the targeted system will be infected and suffers from potential damages.

One recent trend is that malicious code is increasingly using code obfuscation to defeat detection. The presence of obfuscation transformations (such as garbage insertion, code reordering, variable renaming, and encapsulation) obscures the characteristics of a malicious code sequence and has a negative impact on the detection accuracy of a malicious code detection system. A false positive alarm from the detection system distracts the user and complicates the task of malicious code detection. On the other hand a false negative detection outcome runs the risk of allowing malicious code to infect the targeted system. Improving detection accuracy is a critical requirement for this STTR.

Under this STTR, a well-performing and high confidence implementation must advance the state of the art of malicious code (Malware) detection in the following areas:
1. Better code de-obfuscation:
New techniques for identifying and removing the obfuscation are necessary to improve the false negative and false positive rates. Furthermore, the de-obfuscation techniques must integrate tightly with the malicious code detection engine in order to achieve the needed performance and accuracy.
2. Accuracy improvement by reducing false negative rates:
The technology developed must advance the accuracy of malicious code detection in the presence of code obfuscation. Improvement in detection accuracy needs to be verifiable via benchmarking testing.
3. Effective modeling of malicious behavior:
This system should allow domain experts (system administrators, policy makers) to describe the behavior a malicious code. A rich language backed by a large toolbox needs to be developed for the detection system. The malicious behavior model will be used to assist the detection engine to enhance detection accuracy.

PHASE I:
a. Research and develop malicious code detection algorithm that can deal with code obfuscation and enhance detection accuracy.
b. Demonstrate that the proposed algorithm can deal with obfuscated malicious code.

PHASE II:
a. Develop a working system (software implementation) with a behavior model that can capture malicious software.
b. Carry out experiments on synthetic code samples (generated for this purpose) and on actual malicious code sample, each with varying obfuscation levels.
c. Demonstrate the advantages of this approach by comparing against existing tools and techniques for detecting the selected malicious behavior. Benchmarking test needs to be designed and developed to carry out the detection accuracy evaluation.

PHASE III DUAL USE COMMERCIALIZATION POTENTIAL: Security analysis and verification of computer code is important for both the military and commercial communities. Although the information security policies in each community are usually different [5], the detection engine should address any range of policies through the use of multiple models of malicious code behavior as required. The developed detection technology needs to work on both binary code and source code. Such system developed needs to be adaptable to both military and civilian computer systems.

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KEYWORDS: Malicious code detection, static analysis, obfuscation detection and removal, computer system protection

A05-T007 TITLE: Field Sensor for Rapid Weld Hydrogen Assessment

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective of this project would be to design and build a system to measure the hydrogen content of a weld bead area, and test this device in an environment relevant to the manufacturing and repair of large structures (i.e., a factory floor, repair depot, or a shipyard).

DESCRIPTION: Welded steel structures constitute the major share of DoD warfighting platforms. Hydrogen embrittlement of these structures usually occurs through poor welding practices, and is a major quality control issue during fabrication and acceptance. Current industrial practices rely on the certification of the weld process used, the certification of the operator, and the periodic destructive examination of standard test coupons for quality assurance during the welding process. Since the weld conditions for a structure are more difficult and varied than for the test coupons, there is a significant risk that the structure may have very different residual hydrogen than any of the test coupons. Most designers mitigate this risk by using large design factors of safety and generally over-designing the system. The need for high performance, lightweight systems and the frequent specification of modern high strength steels makes this mitigation technique less feasible. In situ inspection for hydrogen is highly desirable, but no reliable test methods have been available.

A recent study [1,2] has shown that hydrogen content effects the thermoelectric power of the material and can be measured by changes in the Seebeck coefficient. A simple four-probe-type sensor system rapidly measures this coefficient for a sample. Since the electronic properties of the material determine the Seebeck coefficient, other measurements using electronic probes are available to measure similar properties directly related to hydrogen content. Placing such a probe on or near the weld bead of a welded structure would provide a quick measurement of the local hydrogen content. This could serve as a quality assurance tool for system Original Equipment Manufacturers (OEMs) by providing qualitative information on the local weld hydrogen content.

PHASE I: This effort shall entail the preliminary design, construction, and demonstration in a laboratory environment of a breadboard level proof-of-concept electronic device to measure the hydrogen content of a welded

steel sample. The demonstration shall include all the necessary modeling and calibration to demonstrate the capabilities and utility of the device in a field environment. The DoD will consider a candidate design with a high probability of successful implementation at the prototype level for further investment during Phase II.

PHASE II: This effort shall implement design developed in Phase I. The awardees shall construct and demonstrate a final, working, prototype hydrogen sensor. A fully successful Phase II effort will finish with the demonstration of a working prototype system in a relevant environment. Further, the DoD expects the device to have significant dual-use application. The awardees shall initiate a plan to further develop, market, and sell a commercial version of the device during phase 2.

PHASE III DUAL-USE APPLICATIONS: This effort may include the field-testing, by a customer organization, of a prototype system such as the one developed in the Phase II effort. This device is expected to have significant dual-use applications in such diverse areas as heavy equipment manufacturing, chemical plant or refinery pipe fabrication and monitoring, monitoring of hydrogen damage during corrosion of aircraft landing gear, etc. The awardees shall work actively to develop commercial partnerships to develop commercial versions of the basic device. This work should include the establishment of optimum operation conditions for the application, development of test techniques and protocols, standards and calibration, and marketing and sales.

MILITARY APPLICATIONS: Ship structures, aircraft landing gear, armor and ground vehicle structures.

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KEYWORDS: hydrogen embrittlement, steel structures, welding, quality control

A05-T008 TITLE: Novel GaN-Based HFET Sources and Amplifiers for Millimeter-Wave Applications

TECHNOLOGY AREAS: Electronics

OBJECTIVE: To design, build and demonstrate a new class of GaN-based Heterojunction Field-Effect Transistor (HFETs) sources and amplifiers where a newly discovered impact mode of operation is utilized to realize enhanced gain and RF output power at millimeter-wave (mm-wave) frequencies and beyond.

DESCRIPTION: The envisioned mm-wave device should build upon recent scientific and engineering breakthroughs in AlGaN/GaN HFET technology that suggest novel new approaches for enhancing high-frequency performance. Indeed, record high RF output power, on the order of 30 W/mm of gate periphery, has been demonstrated from AlGaN/GaN HFET’s [1]. However, in order to achieve this level of RF power from the device excessive applied biasing is required (i.e., Vds ~ 120 volts), which was only made possible through the application of field-plate gate technology. In addition, the RF power was limited to below X-band frequencies (i.e., 8-12 GHz), although theoretical predictions indicate the device should provide useful levels of power well into the mm-wave spectrum. Recent research has demonstrated an IMPATT (impact-ionization-avalanche-transit-time) mode of operation arises within the conducting channel of the device [2]. This mode is established when an avalanche ionization region is triggered by high electric field regions in the conducting channel. The mode enhances the device current and amplifies the output signal and directly suggests a new design methodology whereby a high-power mm-wave sources and amplifiers may be achieved. When this new IMPATT mode concept is combined with emerging techniques for channel engineering [3], it should be possible to counter the traditional limitations imposed by space-charge effects to realize a new class of devices with an order of magnitude improvement in RF performance. These devices will be important to a variety of battlefield applications, such as components in radar and wireless communication systems, and would offer significant operational advantages. Therefore, a focused research and development effort is proposed to enable the full demonstration of GaN-based HFET technology that offers enhanced performance as sources and amplifiers at mm-wave frequencies and beyond.

PHASE I: The first phase of the program should investigate the underlying electron transport mechanisms associated with IMPATT-mode operation of GaN-based FETs and study the associated breakdown mechanisms in the context of alternative structures and geometries. This phase of the project should establish realistic and effective designs for GaN-based sources and amplifiers that are capable of offering enhanced RF operation characteristics at mm-wave frequencies.

PHASE II: In the second phase of the program, advanced design and scaling techniques should be employed to achieve a practical demonstration of GaN-based components at mm-wave frequencies (i.e., ~ 50-100 GHz). This phase of the project should apply advanced modeling to optimize the source and/or amplifier operation. Here, the operational capability of the RF devices should be assessed through detailed measurements and studies should be performed to determine output powers and efficiencies. The new technology should also be implemented to demonstrate the potential utility in radar and/or communication applications.

PHASE III DUAL USE COMMERCIALIZATION: The HFET technology developed under this topic will define a new class of mm-wave sources and amplifiers. The resulting high-frequency devices have important relevance to radar and communications, with the most important applications being mm-wave transmitters for missile beam riders, battlefield communications transmitters, and phase-array radars. The high-frequency electronics components developed under this effort also have implications to high-speed integrated systems for sensing, computing and signal processing.

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KEYWORDS: GaN-based Heterojunction Field-Effect Transistors (HFETs), IMPATT Mode, Millimeter-Wave, Sources, Amplifiers

A05-T009 TITLE: Catalytic Neutralization of Hazardous Chemicals in Ambient Conditions

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: The objective of this effort is to develop screening methodology and new processes to identify and evaluate catalysts capable of chemical agent decontamination under ambient conditions.

DESCRIPTION: Current decontaminants react with chemical warfare agents in a stoichiometric manner, which requires transporting large quantities of the decontaminant, and they often have limited shelf lives. A catalytic decontaminant offers the possibilities of treating larger quantities of agents while having virtually unlimited shelf life and therefore greatly reducing the logistics effort associated with decontamination.

The Army desires to identify active catalysts and classes of catalysts suitable for formulation into catalytic decontaminants. Many catalysts that may be effective for decontamination of chemical warfare agents have been prepared, but not all of them have been tested. For those that have been tested, the tests have not been standardized and catalysts can therefore not be compared or selected with confidence. Existing catalysts primarily function through oxidation or hydrolytic mechanisms and this study should consider including such catalysts as polyoxometalates, more traditional metal oxides, biomimetic hydrolysis catalysts and nanostructured catalysts. The focus in the research for this topic is NOT the development of individual new catalysts, but should be on screening wide classes of catalysts for activity. Additionally, for this topic the catalysts should be preferably screened for use in a solution phase decontaminant.

PHASE I: The contractor shall develop a new methodology that will allow screening for determination of catalyst efficacy for both oxidative and hydrolytic catalysts and will include as wide a range of prospective catalysts as possible. The methodology should include a test plan to be executed in Phase II. The plan must allow comprehensive and thorough measurement of catalyst activity in a cost-effective manner. The Phase I effort will develop a plan for a prototype screening system based on industrially accepted standards for catalyst screening.

PHASE II: The contractor shall apply the new methodology and test plan developed in Phase I to evaluate developmental catalysts for detoxification of chemical warfare agents under ambient conditions. Based on results from this test plan, the contractor will identify the most promising catalysts or types of catalyst for further development. The target prototype system to be developed in phase II will have a process that can be commercially developed for screening catalysts in other industrial areas of need including chemical synthesis, drug development, screening for fuel cell catalysts, and others.

PHASE III: The catalyst screening methodology and prototype system should have commercial potential impacting the fundamental process development in screening catalysts in many areas including drug development, synthetic chemistry, and catalyst screening for fuel cells. Potential opportunities for this technology include new decontaminants for military and first responders, applications of the most promising catalysts to self-decontaminating clothing, coatings, and air filters, and continuing competitive assessments of developing catalysts and decontamination formulations.

PRIVATE SECTOR COMMERCIAL POTENTIAL: Opportunities for developing commercial applications of the technology include marketing the decontamination technology to civilian first responders and industries that handle toxic industrial chemicals, and application of the catalyst assessment methodology to industrial reactions.

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KEYWORDS: decontamination, oxidative, hydrolytic, catalyst, ambient conditions, methodology

A05-T010 TITLE: Dry Sterilization Procedures Based on Variable Frequency Microwave Technology

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

OBJECTIVE: Contamination of sensitive instruments, documents, or equipment with biothreat agents poses a major challenge to eliminate the organisms. This is made especially difficult when the spore-forming bacterium, Bacillus anthracis, is the suspected agent. Anthrax spores are much more recalcitrant to disinfecting agents than are viruses and vegetative cells of bacteria. High-pressure steam sterilization or disinfection with highly corrosive agents, such as chlorine, are effective. But when the contamination is in mail, sensitive paper documents, delicate instruments, or large machines, those procedures are impractical to use.

There is a body of literature that suggests that fixed-frequency microwave energy can inactivate bacterial spores. Thermal effects are the presumed mechanism for killing the organisms. However, some workers have proposed that a second mechanism, termed the “microwave effect,” contributes to the inactivation. Difficulties with the reported experiments are that application of fixed frequency microwave energy includes hot spots, non-uniformity, and uneven heating. Variable frequency microwave technology, however, uses a broadband frequency output with the technician able to select an optimal center frequency that best interacts with the target. The output is swept rapidly to ensure uniform energy dissipation.

Under this STTR, the technology of variable frequency microwave output would be evaluated for use in dry spore sterilization. Optimal process variables would be determined for variable frequency microwave application. Surrogate organisms for B. anthracis would be selected and the killing kinetics would be determined under varying conditions. The information that would be gained from those studies would be applied to the design and testing of a

prototype device. Application of the technology to different biological agents would be monitored. Finally, the applicability of the derived sterilization procedures to additional protective materials, sensitive electronic components, or food packaging would be tested.

PHASE I: Sample spores would be treated in a variable frequency microwave device. The process would be monitored for optimal frequency, target temperature and humidity. Simulated contaminated mail would be tested. The kinetics of inactivation would be determined and compared with conventional dry heat sterilization. Evidence for a "microwave effect" would be sought, and –if verified, would be applied to these experiments.

PHASE II: The data obtained in Phase 1 would be evaluated and applied to the sterilization of different biological species under a variety of conditions. A prototype instrument with properties optimized for surface sterilization would be designed and constructed. The new instrument would be tested for efficacy and practicality.

PHASE III: The technology developed under this STTR would be modified and tested for a variety of applications. The suitability and efficacy of the system in military and civilian applications would be tested. In association with Army laboratories the equipment would be used and monitored against authentic biothreat agents under field conditions.

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KEYWORDS: sterilization, microwaves, spores

A05-T011 TITLE: Pilot-Directed Computer-Assisted Helicopter Formation Flying

TECHNOLOGY AREAS: Air Platform, Information Systems

OBJECTIVE: The objective of this research is to develop the necessary hardware and software algorithms to provide autonomous flying capability for heterogeneous formations of manned rotorcraft vehicles. It is envisioned that this technology would increase flight safety levels and mission success considerably by decreasing pilot workload and fatigue during long and demanding missions.

DESCRIPTION: Modern military combat operations have been greatly impacted by advances in manned rotorcraft vehicle technology. Today's military helicopters offer enhanced mobility, speed, range, versatility and lethality, and day/night capability. This escalating technological complexity coupled with extended mission times has caused an increase in workload and fatigue for helicopter pilots. The advent of aerial refueling has exacerbated the problem with mission flight times commonly in excess of several hours. In addition, missions often require helicopters to undertake the difficult task of flying in formation; where the potential for accidents is increased because of requirements to fly in-close and under extreme conditions including: low visibility (e.g., Instrument Meteorological Conditions - IMC), poor weather, extremely low altitudes (e.g., Nap Of the Earth - NOE), extreme temperatures, high noise levels, and through severe blasts.

The focus of this effort is to develop a predominantly software flight control technology that can be engaged by helicopter pilots to allow autonomous formation flight; thereby reducing pilot stress, workload and fatigue, and increasing flight safety and probability of mission success. Even though helicopter formation flight is of critical importance in military operations, relatively little effort has been focused on this area. Until recently, the complexity and uncertainty of helicopter dynamics had precluded the design of an autonomous controller for even a single helicopter. However, recent advances in system identification techniques and control of rotorcraft-based unmanned aerial vehicles [1, 2] have provided enough insight to make autonomous helicopter formation flight feasible. Additionally, the improvement in flight control technology offered in fly-by-wire systems planned for helicopter upgrade programs (e.g., UH-60M (Blackhawk)) provides a unique opportunity to develop a computer-assisted formation flying aid for piloted rotorcraft vehicles. It is appropriate that research on fixed-wing aircraft formation flying be leveraged for the helicopter problem [5-8]. Additionally, several researchers have made progress on the specific problem of stable helicopter formation flight [3,4], although their concerns were restricted to homogenous formations. To make autonomous helicopter formation flight a reality, several challenges remain: (1) The automation of helicopter formation flying poses a challenge for researchers because formations used in the real world are much more complex than those previously tested under laboratory conditions, (2) the interface and control through the pilot must be accounted for as part of the total system, (3) the demands placed on data/information exchange between aircraft must be kept to a minimum to facilitate optimal use of the spectrum and to retain low EM signatures, and (4) strategies and methods for initiation and termination of the formation must be addressed to ensure maximum mission robustness and safety of the helicopter team.

PHASE I: This phase will demonstrate, through simulation and laboratory-type testing, a conceptual system for pilot-directed computer-assisted helicopter formation flight. The proposed system should address issues such as pilot integration, safety, ease of use, robustness and reliability, ease of fabrication and maintainability, system cost, durability, weight and endurance.

PHASE II: Milestone I - Demonstration of a hardware/software prototype system. The system envisioned will be fully functional for a single piloted helicopter or appropriate surrogate (e.g., remotely piloted or autonomous hobby-type rotorcraft vehicle). Contractor must demonstrate their system's performance in a networked environment with other real or simulated vehicles. Milestone II - contractor must demonstrate their system's performance in a networked environment with other rotorcraft vehicles.

PHASE III: Design, build, and test a demonstration system for a group of no less than four (4) military rotorcraft vehicles. The system will be tested under a variety of environmental conditions to evaluate its robust performance and safety. Successful commercialization will include incorporating this technology into current and future rotorcraft upgrade programs (e.g. UH-60M upgrade program).

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KEYWORDS: formation flying, autonomous rotorcraft, helicopter pilot aid

A05-T012 TITLE: Extreme Phase Change Materials for Soldier Microclimate Regulation

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop next generation phase change materials (PCMs) for personal microclimate systems. These materials are envisioned to function in microclimate systems to enhance cooling system capability, thereby limiting power needs and potentially overall weight to the soldier.

DESCRIPTION: Microclimate systems are being developed to minimize the effects of extreme temperature on performance capability and enable functioning under conditions that would otherwise cause incapacitation. It is important that these systems be highly reliable, lightweight and durable, with the intention to be worn under armor materials, heavy chemical/biological protective suits, and other protective clothing. Current approaches to undergarment microclimate systems involve modular liquid, air, and evaporative delivery systems.
This solicitation seeks the development of next generation phase change materials (PCM) to assist in regulating soldier body temperature in extreme operational environments. These materials absorb or liberate heat through a change in its structure or phase [1]. Sources of heat applicable to soldier climate control are from ambient temperature or normal metabolic processes. Typically, in the absence of physical activity the human body produces approximately 100 W which can increase by over an order of magnitude when performing strenuous activity. Warfighter activity is highly dynamic with variations in metabolic heat production on short time scales. The application of PCMs would lessen the burden to conventional microclimate cooling systems through its proven capability of managing thermal fluctuations [2]. Initial PCM development involved inorganic, salt hydrates. But, due to the corrosive nature of this class of material and its instability, other material systems have been explored. More recently, organic PCMs have been investigated with very promising results. Within this class of materials, molecular alloys have shown great promise and may be tailored in a variety of forms with a correspondingly wide range of PCM attributes [3]. Generally, organic PCMs can be designed over a temperature range of nearly 0°C to almost 200°C and an energy storage capacity approaching 500 J/gm. Interestingly, the salt hydrate and metallic eutectic-based PCMs possess higher latent heats (up to 800 J/cc), but their high densities drive their thermal storage capacity to values comparable to those of moderate organic-based PCMs. Still, degradation in the latent materials attributes remains problematic. For the extreme operating environment of a warfighter, there is considerable development needs for utility in microclimate regulation. Specifically, materials need to be developed that can thermo-regulate core body temperature in hostile temperature environments and thereby enhance the efficiency of conventional microclimate cooling systems. Furthermore, new materials and encapsulation or fabric integration methods would need to be developed that result in outstanding thermal cycling stability. Consideration must also be made in the design of robust PCM-integrated fabrics so to limit weight while not compromising performance.

PHASE I: Develop new phase change materials with enhanced long-term stability above current levels, and latent heats of transformation and temperature transitions appropriate for soldier comfort. Examine the ability of thermo-regulating temperature fluctuations that approximate soldier activity in hostile temperature environments. This would require developing PCMs that have a suitable response time and transition temperature or temperature range to manage these temperature fluctuations. New material systems should be tailorable over a broad temperature range (~0°C to 100°C) and exceed current thermal storage capability by targeting values exceeding 500 J/gm.

PHASE II: Execute performance tests of the PCM material developed in Phase I with microclimate cooling systems to determine its thermal regulation attributes. This test would also require approximating conditions of soldier activity in hostile environments, as discussed in the Phase I effort. Demonstrate the fabrication of a garment integrated with the new PCM or develop new innovative designs to extenuate its capability. Develop a protocol for

optimizing its operation based on textile fabrication techniques, such as extrusion processes, and optimization of materials. Verify the strength and ruggedness of the fabric through rigorous performance studies.

PHASE III DUAL USE COMMERCIALIZATION: These materials will enable cooling systems that could be used in a broad range of military and civilian security applications where individual climate control is necessary, including soldier and first responder uniforms and protective equipment, as well as vehicle hulls, tents and other outdoor materials, and advanced building materials.

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KEYWORDS: Phase Change Materials Cooling

A05-T013 TITLE: Integrated Thermoelectric Cooling of Photodetector Arrays for Uniformity and Operability

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics

OBJECTIVE: Develop technology to monolithically integrate passive thermoelectric devices with infrared photon detector arrays to improve low-temperature pixel-to-pixel uniformity and operability.

DESCRIPTION: Future infrared focal plane array (FPA) structures are envisioned to have multi-color functionality with a megapixel format. Reduced operability due to non-uniformities often occurs as the result of the ubiquitous presence of defects such as dislocations within the detector material. This occurs at all temperatures but generally becomes worse at lower operating temperatures, especially below 77 K. However, it is known that an improvement in uniformity can be obtained by slightly shifting the temperature of each pixel in the FPA. This topic focuses on developing innovative technologies for monolithically integrating thermoelectric devices with infrared detector structures to provide novel temperature control. The thermoelectric device is not intended to cool the FPA to its operating temperature around 77K but rather to adjust the operating temperature to cancel non-uniformities. The first choice is for a passive system that operates by the conduction of the electrical photocurrent and dark current that is generated in each of the individual infrared photodiodes of the infrared FPA. The passive conduction of photocurrent through the thermoelectric device will cause a temperature change at the pixel level. This photocurrent is on the order of 10 - 100 nanoamps and the temperature adjustment required would be on the order of a few Kelvin. Nanoscale superlattice structures, which have a delta-function distribution of density of states and energy levels due to three-dimensional confinement, a potentially more favorable scattering mechanism, and a much lower lattice thermal conductivity, provide the potential to obtain this temperature control [1,2]. The result of the temperature change would be to reduce the effect of defects on the operability of the FPA. This benefit will yield improved performance in NEDT and resolution for future FPA structures. In this topic all FPA technologies will be given consideration, however priority will be given to HgCdTe structures. In addition, circuits that require active control or a separate power supply for the thermoelectric cooling will also be considered, but priority will be given to passive structures that will achieve the required temperature change. Precise thermal management techniques would also be useful for integrated, high-power RF devices and spot cooling high-bandwidth optical interconnects.

PHASE I: Design, grow and process passive thermoelectric devices. Measure ZT and demonstrate cooling/heating potential by active thermoelectric cooling.

PHASE II: Fabricate monolithically integrated passive thermoelectric devices with detector structures. Demonstrate temperature change of a detector with cooling from an integrated device.

PHASE III: Besides infrared detectors, a large number of defense and commercial applications will benefit from integrated low cost temperature control. For instance, an integrated, passive thermal management technology would contribute to better thermal control and improved resistance to current collapse of AlGaN/GaN HFETs. These would be used in longer range RF communication systems as well as higher resolution and longer range radar systems. Also, an integrated passive thermoelectric device could help to alleviate the thermal build-up within vertical cavity surface emitting lasers used in arrays for optical interconnects. For this STTR, a Phase III effort should be devoted to developing a large scale manufacturing process for arrays with integrated cooling.

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KEYWORDS: thermoelectric cooling, HgCdTe, superlattice, passive thermal management

A05-T014 TITLE: Development of Innovative Computer Hardware and Software for in Silico Screening

TECHNOLOGY AREAS: Chemical/Bio Defense, Information Systems, Biomedical

Rationale: The identification of potentially vulnerable sites in the pathogenesis of a biothreat agent is critical to the development of countermeasures to control the infection. Defining such sites has been accelerated recently by involving new genetic and molecular biological approaches to understand the infective processes. However, once a critical enzyme or receptor binding protein is identified, the discovery of inhibitors for those proteins relies on testing a very large number of suitable compounds in a high-throughput screening process. This is based on the premise that the larger the number and the greater the diversity of compounds studied, the better the chance of finding those that could be developed into an anti-infective drug or inhibitor of the protein. Laboratory scale in vitro screening is extremely expensive, labor intensive, time consuming and dependent on a having a suitable assay procedure. The process could be greatly accelerated by a highly reliable preliminary in silico screening of libraries of known compounds. This STTR will exploit computer technology and very large databases of small molecular weight compounds to develop a user-friendly and relatively low-cost but extremely rapid in silico system for calculating binding energies for specific proteins and potential inhibitor/activator compounds. By in silico testing the “fit” of a large number of compounds and their various solution structures the screens for in vitro activity could be severely reduced, and the process of developing effective countermeasures greatly accelerated. When the proposed system is developed, the process of drug discovery could be reduced from years to weeks.

OBJECTIVE: The objectives of this STTR are to develop rapid, specific, innovative, and highly effective computer-based hardware and associated software for screening small molecular weight compounds as preventive and/or remedial countermeasures against biothreat agents.

DESCRIPTION: Countermeasures against a biothreat agent may neutralize the agent, prevent its association with sensitive cells or tissues, intercede the disruptive functions in metabolic targets, or provide massive surrogate sites to frustrate activity. Such defensive efforts may act against a specific threat or be generally effective for a group of related agents. A search for such inhibitors is arduous, expensive, and time consuming, using the conventional laboratory screening procedures. This assumes that a reliable assay is available to use for such a screen. A major breakthrough in silico technology would be a reliable and rapid screening regimen of small molecular compounds that specifically preclude a critical activity of the threat.

A computer-assisted mechanism, wherein individual components of a complex library could be computationally fitted to the critical binding site of the agent would shorten considerably the search for potential inhibitors. The purpose of the STTR is the innovative application of computer hardware and associated software for computer-based screening procedures. Compounds identified by that program would then be tested in vitro and in vivo as agent countermeasures. The overall goal of this STTR is to develop in silico regimens for assigning binding energies as a basis for predicting the efficacy of potential inhibitors for biothreat interaction. Where a suitable inhibitor could not be discovered in a given library, based on the compounds that had been tested, the system to be developed

should be able to predict compounds or structural modifications of existing library compounds that would have suitable binding energies to act as effective inhibitors.

The technology to be developed under this STTR would have military and civilian applications. Specific interference with a critical function in a biothreat infection would provide the least disruptive and earliest possible defensive measure for the host.

PHASE I: During Phase I a novel computer system would be developed to permit in silico screening of databases with docking programs that are 10-100 times faster than the speed of a conventional computer. The docking program would be optimized for calculations on the novel computer. An operating system for data communication, including data storage and access, would be developed.

PHASE II: The novel computer system would be optimized for in silico screening with a speed that is 1000 times faster than the speed of a conventional computer. A user-friendly graphics interface would be developed with interactive tools and molecular modeling utilities. Using the ricin protein, potential inhibitors would be selected, using the newly developed program.

PHASE III: The technology developed under this STTR would be modified and tested for a variety of applications. The generality and efficacy of the system in a multitude of military and civilian applications would be tested. In association with collaborative Army laboratories, inhibitors of potential biothreat agents would be selected for testing, based on the assigned binding energies derived from the computer-based screening.

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KEYWORDS: in silico screening

A05-T015 TITLE: Visible Wavelength Negative Index Materials

TECHNOLOGY AREAS: Materials/Processes, Sensors

OBJECTIVE: Develop optical materials exhibiting negative index properties that operate in the visible or near IR, and use such a material to create a lens that can perform subwavelength imaging; enhanced resolution imaging; or that can be used as a flat lens.

DESCRIPTION: Negative Index Material (NIM) effects have been demonstrated in the microwave region [1,2] but no NIM has been made that operates in the visible or near IR (visible to 5 or 10 microns). It has been shown theoretically that such a material could make a perfect lens, i.e., a lens that can overcome the diffraction limit, because it allows the high frequency modes that are otherwise attenuated by a conventional lens. It has also been noted that flat NIMs could produce imaging, which has been demonstrated in the microwave regime but not yet in the visible. Dielectric materials embedded with nano-rod conductors may be one route that leads to visible wavelength NIMs, but no such material currently exists. Photonic band-gap crystals have also been shown to exhibit NIM-like behavior in the microwave. It is expected that this design can be carried over to the visible. (Anisotropic materials have also been shown to exhibit negative refraction, but this project is not seeking to use anisotropic materials.) Such lenses, based on NIMs, would allow for high-resolution imaging and subwavelength focusing. The most immediate applications are in imaging (lenses) and nanolithography. Military applications include flat optics that could be conformally embedded on visor and imaging systems and in the development of new nanolithographic structures for photonic applications. The uses also have strong commercial application, such as the development of switching devices and high speed routers from the subwavelength photonic materials and myriad uses in imaging, from cameras to surveillance devices. The objective of this project is to develop a NIM lens that operates in the visible and is capable of subwavelength imaging or producing other novel NIM effects that conventional lenses are incapable of producing, such as the flat lens.

PHASE I: Design a NIM material and show feasibility that it will have NIM behavior in the visible or near IR. Design a demonstration that will show it has NIM behavior. A successful demonstration, for example, would be to show that the material would produce negative refraction. Describe how the NIM will be manufactured.

PHASE II: Manufacture NIM material and build an optical lens. Prove that it exhibits NIM behavior and demonstrate subwavelength imaging or some other effect conventional optics is incapable of producing. Examples here would be to build a flat lens, or a lens that focuses beyond the diffraction limit.

PHASE III: Build military imaging system using the NIM material.

DUAL USE APPLICATIONS: Relate to commercial applications such as nanolithography, enhanced resolution imaging, or the flat lens. Imaging beyond the diffraction limit could allow for a new class of industrial nanolithography and make possible an entirely new kind of nanomaterials, while flat lenses could be used on everything from displays to sensors. Other commercial applications include the development of switching devices and high speed routers from the subwavelength photonic materials and myriad uses in imaging, from cameras to surveillance devices.

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KEYWORDS: Negative index materials, left handed materials

A05-T016 TITLE: Heavy-Tailed-Statistics-Based Routing Policy for Ad Hoc Wireless Networks

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop ad hoc wireless network routing policy(ies) that minimize heavy-tailed-statistics-based quality-of-service metrics

DESCRIPTION: In communication networks, the quality of service (QoS) provided to the user is an important factor. Previously, models based on Poisson, Gaussian and other classical distributions with exponentially decreasing tails were often used to model network traffic and to define QoS metrics. Many QoS metrics in current use are average-based metrics—for example, average reception delay, average number of hops, average jitter,

average number of packets lost—derived from these classical distributions. It is now recognized [1,2] that traffic in wired and wireless communication networks is better described by heavy-tailed distributions than by Poisson, Gaussian or other classical distributions with exponentially decreasing tails. Investigation of heavy-tailed-statistics in wired networks has been expanding over the past decade and, for this reason, wired networks will not be considered in this solicitation. The focus of this effort will be the application of heavy-tailed-statistics-based QoS metrics to multi-hop ad hoc wireless networks. Of interest here are completely wireless networks (no wired backbone).

For heavy-tailed distributions, median-based procedures, which correspond to minimization of L1 norms, that is, of sums of absolute values, are more accurate and robust than average-based procedures, which correspond to minimization of squares of L2 norms, that is, of sums of squares (see [3] and proceedings of prior conferences in this series). The many "outliers" in the heavy tails make average-based procedures unreliable but do not significantly affect the outcome of the more robust median-based procedures. This suggests that heavy-tailed-statistics-based QoS metrics may better be expressed using L1 norms than using sums of squares (L2 norms). Other non-L2-norm-based metrics such as outage have been considered recently and could be considered in this project as long as they are shown to be based on heavy-tailed statistics. Any computationally tractable (not exponentially expensive) metrics based on heavy-tailed statistics are acceptable.

PHASE I: Determine one or more practically useful and theoretically well founded heavy-tailed-statistics-based metrics for measuring QoS in multi-hop ad hoc wireless networks. Justify this/these metric(s) by describing all of the steps that lead from the heavy-tailed characteristics of network traffic to the formulation of the metric. Based on these metrics, design one or more routing policies with guaranteed computational feasibility. Computational feasibility implies implementability in a real-time, distributed, scalable fashion. Globally computed routing policies are in general exponentially expensive and therefore infeasible. Once the steps from the underlying statistics to the QoS metric to the routing policy have been justified, the work consists in investigating the influence of the routing policy on network performance, with the objective of achieving improved network performance. Implement the routing policy(ies) in a simulation system and demonstrate feasibility for networks consisting of hundreds of nodes.

PHASE II: Finalize the formulation of the routing policy(ies). Carry out extensive validation and verification of the routing policy(ies) by physical experiments for networks consisting of hundreds of nodes or more. The experiments may be wired as long as the results are directly applicable to wireless, that is, include analogues of wireless interference, abruptly changing connections, fading, etc. Validation and verification should confirm that the theoretical predictions of performance (including computational overhead) developed in Phase I and early Phase II are correct or should provide guidance for appropriate adjustments. Carry out computational and/or experimental comparisons of these policies with one or more standard routing policies based on Poisson, Gaussian or other classical statistical assumptions. Identify limitations of the heavy-tailed-statistics-based routing policies and determine whether these limitations are due to fundamental technical barriers. At the end of Phase II, carry out a demonstration that globally compares a system with heavy-tailed-statistics-based routing policies and a system with classical-statistics-based routing policies.

PHASE III DUAL USE APPLICATIONS: In Phase III, the recommended routing policy(ies) should be implemented in wireless networks designed for use in various military and civilian situations.

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KEYWORDS: heavy tail, metric, network, quality of service, wireless

A05-T017 TITLE: Fabrication of 3D Photonic Crystals in the RF Range for Man-Portable Antenna Applications

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective of this program is to design and fabricate a metallodielectric resonant structure, commonly known as a photonic band gap (PBG) material, that is active in the RF range (MHz to GHz) for helmet-mounted antenna applications. The emphasis of this program is to take advantage of the PBG material's unique properties for novel RF propagating structures that will enhance war fighter situational understanding and battle command without adversely effecting war fighter mobility.

DESCRIPTION: Mounting the antennas of personal communications systems (voice-radio, digital network, GPS etc.) onto the helmet of the soldier offers many practical advantages. The primary drawback is the poorly controlled coupling of energy into the body, which significantly effects range and power. Photonic band gap (PBG) crystals allow the manipulation and control of electromagnetic waves and have wide applicability in optical communications, optical physics, RF technology, and many other areas. PBG structures for RF can take many forms, from the simple cm-scale arrays of beads [1] to the arrays of so-called Jerusalem Cross Structures [2, 3] in some compact systems. The cost effective design and processing of these composite materials into compact, robust, tailored structures, particularly helmet-mounted antennas, limits their application. It is the goal of this project to develop and apply techniques for modeling, design, and fabrication of PBG materials with performance metrics relevant to helmet-mounted antennas for military applications. The emphases are size, weight, and power (SWaP); RF material parameter suitability for the specific application; and material integration.

PHASE I: This effort will entail preliminary PBG design, fabrication plan, and predictive modeling efforts. Innovative and mature ideas are encouraged. The offeror has discretion in the exact final application, which may include the personal voice radio, GPS, wireless LAN, etc. The awardee shall develop an integrated communications system design that includes the new antenna system, a design of the antenna that includes a detailed design of the PBG material used, and the use of modelling and simulation to predict the performance enhancement offered by the new antenna system. The awardee shall also develop a fabrication plan for the PBG material that is suitable small-scale production (25-50/month maximum in a dedicated facility) of prototype systems for field-testing. The success of the Phase I effort will be judged on the level of anticipated likelihood of success in the planned Phase II effort, the level of enhancement predicted in the communications system, and the operational importance of the target application.

PHASE II: This effort will implement design developed in Phase I. The awardees shall demonstrate the final working prototype helmet-mounted antenna system using the PBG material. A fully successful Phase II effort will finish with a working RF military prototype system that is suitable for testing in a relevant environment. In addition, the awardees shall initiate a plan to further develop, market, and sell a commercial antenna system using the material.

PHASE III DUAL-USE APPLICATIONS: This effort will include possible field-testing of the system developed in the Phase II effort by a customer organization. It may also include the application of the design to other, related systems or to commercial products including cellular phone antennas, "Bluetooth" equivalent communications systems, implantable medical diagnostic devices, etc. The awardees shall work actively to develop commercial partnerships to design commercial versions of the basic device. This work should include the establishment of optimum operation conditions for the application, development of test techniques and protocols, standards and calibration, and marketing and sales.

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KEYWORDS: Photonic Bandgap Materials, Periodic RF Structures, antennas, crystalline arrays, fractals, periodically doped crystal structures

A05-T018 TITLE: Reducing Complex Physico-Chemical Model Systems

TECHNOLOGY AREAS: Information Systems, Weapons

OBJECTIVE: Create desk-top computer-based programs and documentation to enable analysis of complex science and engineering models and experimental data sets using recently developed functional Sensitivity Analysis (SA) and High Dimensional Model Representations (HDMR). The tools should be designed so that practicing scientists and engineers who are not experts in the theory of data analysis, can use them and understand their output.

DESCRIPTION: Consider a system as having inputs (e.g., components, initial conditions) and outputs (e.g., observables in an experiment). A classic problem in science and engineering requires the investigator to understand the system by analyzing the observables. We often approach this problem by creating a model with selected inputs and compare the model outputs with observations; if they agree the model may represent the (tested) part of the real system. That model will likely not be unique. Determining the inputs and initial conditions on which the outputs depend most strongly is called Sensitivity Analysis (SA) and some standard statistics software packages include SA modules. SA has the potential to enable us to understand how outputs depend on inputs, to keep those inputs in our model that most influence the outputs of interest, and to reduce complex models (and their computation) to their essence. Identification of the most important inputs also enables us to reduce the number of experiments required to characterize a system.

Commercial software packages providing a wide range of statistical analysis of data have been available for several decades. These packages are very general, run on personal computers, and the best come with clear manuals so non-specialists can carry out informed analyses of their data. The current commercially available SA modules enable simple "parametric" sensitivity analysis but more sophisticated, modern, and information-rich analyses are only available to experts who write their own codes. Beyond parametric sensitivity analyses are functional sensitivity analysis and beyond that, High Dimensional Model Representation (HDMR). Within the past decade, HDMR has been explored and developed (Li et al., 2001) and applied to a wide range of physical and engineering problems. These applications have developed input/output relations for a wide range of data sets and developed functional relations including:

a. Quaternary semiconductors composition to electronic band gaps;
b. Molecular potential energy surface to observed scattering cross sections;
c. Global stratospheric chemical modeling;
d. Solar radiation transport through the atmosphere.

This new STTR project will require the implementation of recent theoretical work on input/output relations, especially where those relations are nonlinear and so will require expertise in SA and HDMR. The implementation will provide accessible software modules written and documented to be user-friendly; that is, a scientist and engineer with reasonable background in mathematics and data analysis using a computer (this includes many practicing scientists) will be able to understand and use these tools and to understand their output.

PHASE I: The Army intends these tools for use by DOD scientists and engineers, therefore we recommend a demonstration of feasibility on a specific problem of DOD interest. An important example of a current important Army problem is the reduction of chemical kinetics models of propellant flames. These combustion systems can be characterized by many kinetic equations involving very many chemical species. These models become too large to be useful and we wish to use the analysis to explore whether the model can be reduced without degrading predictions of flame speed and spatial distributions of major combustion components. The STTR contractor should develop a demonstration of this very broadly applicable software by focusing on this specific combustion problem. Input data will be made available by Army scientists.

PHASE II: Following successful demonstration of feasibility, the principal effort will be to establish the codes for a range of advanced methods to reduce high dimensional models. The programs will be written efficiently so that they will run on a desk top computer. The programs will enable straightforward and convenient data entry. Computed outputs will be available as computer files and as visualizations on the computer screen. Documentation will aid the user to choose the specific implementation best suited to evaluate the data model, perform the computation, and evaluate the results. The programs will include tutorials on the underlying mathematics and their

physical significance. The contractor will demonstrate this product for Army scientists and engineers at an Army laboratory.

PHASE III DUAL USE APPLICATIONS: The study of any complex system involving multiparametric inputs and outputs will benefit from advanced SA. This includes much of modern day science and engineering and a successful project will have major impact in broad areas (physical, biological, medical, social). Examples of model systems that could be explored using this software include: atmospheric chemistry, cominatorial chemistry scanning for catalysts or pharmaceuticals, the establishing of operating conditions for multistep syntheses, and determining optimum designs for composite materials.

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KEYWORDS: sensitivity analysis, reduced data sets, data analysis, high dimensional models

A05-T019 TITLE: Embedded Sensors with Mechanics- based Models to assess Military Systems made with Composites

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop: (1) a suite of sensors that provide time-history data for moisture content, UV exposure, and strain, and (2) mechanics-based models to provide an accurate assessment of the state of the military platform. This paradigm shift from current practices is required to overcome the deficiencies associated with material degradation from multiple environments and loading conditions.

DESCRIPTION: The military use of composite materials systems continues to suffer from a lack understanding of how corrosive environments in combination with applied loading affect durability. Over the system's life-cycle, complex interactions can alter material properties, structural performance, and lead to failures. Many studies have been performed to address these issues, but the history-dependence and complexity of coupled factors necessitate a new approach that combines data from sensors with mechanics-based models.

During system operation, composites are often susceptible to moisture, UV radiation and mechanical loading. In some cases, the conditions may counteract each other and in others they may act synergistically to compound the degradation process (Gates, 1999, Kumar 2002). The overall behavior is dependent on the exposure history. In all cases, exposure to environmental conditions and mechanical loading leads to a severe reduction in mechanical properties, unpredictable microstructural failures and a decrease the life-cycle of the platform. To determine the component's condition, maintenance crews rely only on visual inspection, which can be misleading since undetected microscopic or sub-surface cracks may lead to catastrophic failure. The results from an integrated modeling/sensing tool should give users an accurate assessment of the military platform's condition. Structural degradation is also an issue in the design stage where engineers rely on test procedures performed at the coupon level on pristine specimens. Life cycle predictions are done sequentially without accounting for the combined effects of multiple degradation processes or mechanical loads. They rely on outdated empirical models that are gleaned from limited data sets. The drawbacks of the current design process necessitate the use of large factors of safety and cast doubt as to whether the components are over or under designed.

There have been recent breakthroughs in low cost sensor fabrication as well as computational modeling that will enable the development of sensor systems to monitor degradation and damage. On the fabrication side, the MEMS community has begun to develop new methods to fabricate devices using materials other than silicon. For example, thermal spray processing allows a wide range of materials (metal, ceramic, or polymer) to be deposited in desired patterns on almost any substrate (Wan, 2000, Longtin, 2004). Piezoelectric and piezoresistive materials have also been used for MEMS sensor devices (Pryputniewicz, 2000). Cost effective Dip Pen Lithography (DPL) techniques have been developed using massively parallel arrays of cantilevers that can deposit piezoelectric or conducting polymers to create new MEMS sensors (Zhang, 2002). Fiber optic sensors have also been incorporated especially in composite materials that use continuous fiber reinforcement. As fabrication methods have advanced they have

steadily reduced the size of the sensors. Some sensors are now fabricated in the nanometer range. Such reductions in size should be beneficial in ensuring that the sensors can be seamlessly integrated into structures, are capable of withstanding harsh environments, and do not disturb the system that they are interrogating.

PHASE I: Develop test apparatus and procedures to allow for combined degradation mechanisms and multiaxial loading. Use this test bed as a platform to retrieve data from composite specimens with integrated sensors. Test the feasibility of an integrated modeling/sensor tool by developing mechanics-based models that utilize the data to provide insight into the relationship between structural integrity, environmental conditions, and applied loading.

PHASE II: Improve the system created in Phase I to develop a protocol for analyzing material systems for life predictions. Scale-up from coupon level to component level testing.

PHASE III: Demonstrate and extend the use and applications of the integrated modeling/sensor tool to monitor and predict damage accumulation in commercial and military system components from environmental degradation under operating conditions.

DUAL USE APPLICATIONS: Will include lightweight body armor systems (NIJ Special Report, 2004), military vehicles, composite rotor blades, aircraft components, offshore marine platforms, automobiles and marine components. The recipient should be able to incorporate embedded sensors into composite components to obtain relevant data to assist in making an accurate assessment of marine, aircraft or military platform's condition.

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KEYWORDS: Integrated sensors, environmental conditions, degradation, mechanics-based models, composite materials, durability

A05-T020 TITLE: Synthetic Gills

TECHNOLOGY AREAS: Materials/Processes, Biomedical

OBJECTIVE: To develop advanced synthetic membranes and storage systems based on the biological gill-swim bladder system and create a unique breathing apparatus capable of gathering, storing, and delivering a supplementary supply of oxygen to enhance respiration in either underwater or high altitude environments.

DESCRIPTION: Molecular transport mechanisms in cellular membranes, which are inherently both efficient and selective, provide tremendous motivation for utilizing these mechanisms in synthetic materials. Among the various transport mechanisms utilized by cellular membranes, active transport, which employs integral protein "pumps," affords the unique capability of solute transportation against a concentration gradient. In marine biology, gills utilize hemoglobin to absorb oxygen from the water and transport it to the swim bladder for storage. This gill-swim bladder system constitutes an ideal model from which to design a novel breathing apparatus suitable for enhancing respiration in either underwater or high-altitude environments.

Underwater and high altitude warfighter activity is severely limited by conventional breathing apparati. The size, weight and logistical requirements for this equipment complicates its deployability and sustainability, restricting its use to but a very few types of operations. An advanced breathing apparatus capable of functioning with the simplicity and robustness of the gill-swim bladder system found throughout marine biology would significantly improve warfighter deployability, sustainability and maneuverability for a wide array of aquatic and high altitude operations.

Advances in molecular biology now provide a variety of tools capable of determining the quantitative tissue-specific and spatial distributions of the transport proteins which govern the gill-swim bladder system at the molecular scale. These tools enable robust and rapid characterization of the structure, dynamics and function of these transport systems. Furthermore, recent breakthroughs have demonstrated the ability to reconstitute biological transport proteins and to insert them into synthetic materials while retaining their functionality.

What is expected from a successful effort is the creation of a unique breathing apparatus, based on the phenomena observed in the gill-swim bladder system found in marine biology, capable of extracting and storing oxygen directly from a marine or high altitude environment and delivering it to the warfighter. Identification and characterization of the structure, dynamics, and selectivity of the critical transport proteins governing oxygen transport in the gill and swim bladder is expected to significantly enhance the efficiency of the resulting design. Identification and design of optimal fluids to facilitate oxygen transport is also expected to significantly improve design performance. The use of novel synthetic membranes to facilitate active transport of respiratory gasses is expected to provide the breakthrough absorption and collection properties necessary to develop a functional apparatus.

PHASE I: Design and demonstrate synthetic membranes and storage systems to provide optimal oxygen extraction and storage from a marine or high altitude environment. Select, fabricate, and demonstrate an optimized material solution and provide a quantitative characterization of oxygen extraction and storage capacity in both marine and high altitude environments. Develop a conceptual design for a complete breathing apparatus using these results, including estimates of the capabilities and requirements of a complete system.

PHASE II: Construct a prototype design for a novel breathing apparatus and demonstrate the capabilities of the design for sustaining a warfighter underwater and at high altitudes. Refine and optimize power and storage capacity requirements to meet specific warfighter and/or commercial needs.

PHASE III DUAL USE COMMERCIALIZATION: These novel membranes and storage systems will enable unique breathing apparati for a broad range of military and civilian use, including that by warfigthers, first responders, climbers, construction and salvage workers, and athletes.

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KEYWORDS: Underwater High Altitude Breathing Apparatus

A05-T021 TITLE: Infrared Derivative Spectroscopy for Open Path Sensing

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

OBJECTIVE: Develop and evaluate novel open path infrared sensing systems that exploit optically engineered methods to generate derivative spectral signatures of hazardous organic vapors such as chemical warfare agents (CWAs) and other hazards including biological particulate matter such as biological warfare agents (BWAs). By generating the derivative spectra using optical vis-à-vis mathematical (after the fact), then the signal-to-noise ratio (SNR) of the spectral signature of the sensed species is enhanced, and broad background clutter signal is reduced or eliminated.

DESCRIPTION: Chemical and biological warfare agents present a significant threat to Future Combat Systems and Homeland Defense operations. The Department of Defense is developing and evaluating the next generation of chemical and biological sensor technologies for early warning protection of potentially exposed personnel. Infrared spectroscopy extracts unique spectral fingerprints of organic compounds from open-path signal acquisitions, facilitating the unambiguous identification of CWAs and other toxic industrial chemicals, and more recently from bio-aerosols. However, sensing trace hazards remains a challenge for open-path systems because of the limited absorption cross-sections and low analyte concentrations that are representative of the threat species. One way to enhance the spectral signature of the contaminant against the broad atmospheric background is to perform a first- or second-derivative on the measured signal, which will enhance the sharp spectral features of the analyte relative to the broad spectral continuum presented by the atmospheric background. Performing the derivative function mathematically on the acquired signal also affords some resolution enhancement, which is particularly useful for the analysis of the subtle fingerprint spectra of biological hazards. Mathematically realized derivative analysis does not afford any enhancement to the detection limit of trace analytes because the original signal is not enhanced, and most of the digitization bins of the analog-to-digital converter (ADC) represent the background rather than the analyte. Techniques for developing a derivative spectrum optically can potentially enhance the performance of open path systems for infrared hazard detection by presenting an enhanced SNR to the detector. This solicitation seeks any hardware approach toward developing first- or second-derivative infrared spectroscopes for open path sensing in the mid infrared (3-30 microns) region, with particular emphasis on the long wave infrared region (8-12 microns). Any innovative method for acquiring and analyzing derivative spectra would be responsive to this solicitation.

PHASE I: Phase I shall consist of a comprehensive optical engineering design review and a mathematical model of an infrared system for acquiring derivative spectra. The product of the Phase I effort will be a detailed engineering design and a performance model that predicts the optical throughput and sensor performance given a suitable model of a threat scenario (e.g., a chemical agent cloud in a given optical path). The modeling effort should include a performance model of a conventional Fourier transform interferometer as a baseline system to quantify the benefits of the derivative spectroscopy approach versus the state-of-the-art.

PHASE II: An engineering development and prototype construction effort will comprise the Phase II effort. At the completion of the Phase II effort, a prototype open-path derivative spectrometer that performs as either a passive spectroradiometer or a monostatic or bistatic open-path derivative spectral data acquisition will be manufactured and delivered.

PHASE III: The technology developed in Phase II will either be licensed to a sensor manufacturer or the performer will partner with a sensor manufacturer for the development of an inexpensive commercial sensor based on infrared derivative spectroscopy. Applications include, but are not limited to, environmental remediation, hazardous air pollutant sensing for public/workforce protection, and air quality monitoring applications.

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KEYWORDS: Spectroscopy, infrared, remote sensing, open-path, biological warfare agent, chemical warfare agent, spectral sensor, detector, air monitor

A05-T022 TITLE: Manned, Standalone, and Unmanned Aerial Vehicle Portable Sensors for Detection of Biological Warfare Agents

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: To research, design, and develop portable, lightweight, microfluidic microchip and cartridge based, and user-friendly biosensors that are capable of automated and rapid detection of biological warfare agents (BWA), can perform in unmanned aerial vehicle (UAV), standalone, and point detection applications, with high sensitivity and specificity for all classes of bioagents.

DESCRIPTION: Current fielded and laboratory based biodetection technology is generally macro or meso sized; requires high power input; carries a large logistical load (reagents and consumables); and in many cases, requires direct operator involvement in one or more of the assay steps. A number of fielded systems, in particular are usually mounted in a Highly Mobile Military Vehicle (HMMV) as part of a total biodetection suite. In order to acquire the necessary situational knowledge of the battlefield or area to be maneuvered through, in a more efficient and flexible manner, highly portable, user-friendly, automated, low logistical load (i.e., reagents and consumables), rapid, and microfluidic microchip and cartridge based biosensors are needed to allow for broader and faster area coverage. Specifically, biosensors are needed that can be used in UAV based area reconnaissance, and standalone, and point biodetection applications.

PHASE I: The Phase I effort will establish proof-of-principle for the biosensor technology being developed. The thrust of the effort must be consistent with the objective and description of this topic. The following specific goals are provided to augment the overall guidance.

a. The biosensor technology must be geared toward UAV, standalone, or point detection mission capability with an eye toward the advanced prototype development called for in Phase II. Biosensor technologies that are capable in two or all three of the mission categories are highly recommended. In the case of multi-purpose biosensor technologies, little to no modification is expected in order to adapt them to the different mission classes.

b. The biosensor technology must be able to detect bacteria (spores and vegetative), viruses, and proteins. BWA simulants and model microorganisms and proteins must be used for the Phase I initial studies, although BWA simulants are recommended. For Phase I, the individual simulant or model bioagent assays may first be developed and optimized in pristine buffer. One optimized assay for each must be demonstrated. Interferent studies, using aerosol and surface swipe milieus, spiked with each of the simulants or model bioagents, must also be performed to assess the robustness of the biosensor technology, as well as, to gain an idea of how much sample preparation and processing will have to be involved in the assay process.

c. The biosensor technology must detect each event unambiguously in less than 30 minutes.

d. The biosensor technology must have a sensitivity of less than or equal to 10^4 CFU/ml (colony forming units per milliliter) for bacteria (spores and vegetative), less than or equal to 10^6 PFU/ml (plaque forming units per ml) for viruses, and less than or equal to 10 ng/ml (nanograms per milliliter) for proteins.

e. The biosensor technology can be semi-automated for Phase I.

f. Development of a biosensor technology that allows for regeneration of the assay surface is highly recommended.

g. The biosensor technology must be capable of continuous operation for approximately three hours.

h. Sample preparation and processing are not required for Phase I but should be thought about early on for Phase II implementation. The results of paragraph b above should provide a general direction to proceed. The Phase 2 advanced biosensor technology prototype system must be able to unambiguously detect both aerosol and surface swipe derived samples.

i. A biosensor technology laboratory benchtop breadboard prototype must be demonstrated to have the requisite parameters discussed above.

PHASE II: The Phase II effort will provide an advanced prototype with capabilities consistent with the objective and description of this topic. The following specific goals are provided to augment the overall guidance.

a. The advanced prototype must be able to detect bacteria (spores and vegetative), viruses, and proteins. Inactivated BWA agents (bacterial spores, vegetative bacteria, viruses, and toxoided protein toxins will be used for the Phase II effort. The individual bioagent assays may first be developed and optimized in pristine buffer. One optimized assay of each must be demonstrated. Continuing interferent studies, using aerosol and surface swipe milieus, spiked with the bioagents, must also be performed in conjunction with the sample preparation and processing development (paragraph f below) to reach a point where the optimized bioagents in pristine buffer assays and the sample preparation and processing assay results are equivalent.

b. The advanced prototype must detect each event unambiguously in less than 20 minutes.

c. The advanced prototype must have a sensitivity of less than or equal to 10^3 CFU/ml for bacteria (spores and vegetative), less than or equal to 10^5 PFU/ml for viruses, and less than or equal to 1 ng/ml for proteins.

d. The advanced prototype must demonstrate simultaneous detection (i.e., multiplexed) of all the BWA classes used in the effort.

e. The advanced prototype must weigh less than 30 lbs and occupy no more than a 1.5 cu.ft.

f. Sample preparation and processing must be incorporated into the advanced prototype biodetector, either by direct integration or as an attached component. The advanced prototype must be able to unambiguously detect both aerosol and surface swipe derived samples.

g. The advanced prototype and the sample preparation and processing module must be fully automated and be capable of continuous operation for approximately three hours.

h. Again, in the case of multi-purpose biosensor technologies, little to no modification is expected in order to adapt them to the different mission classes.

i. The advanced prototype must be demonstrated to have the requisite parameters discussed above, and serve as a deliverable for independent Government evaluation.

PHASE III DUAL USE APPLICATIONS: Example applications of the topic technology are as follows.

a. Department of Defense: Area monitoring and reconnaissance prior to entry, critical asset protection, biological attack warning, Technical Escort Unit (TEU) mission analyses, medical monitoring, and water analysis

b. Other Government agencies: Homeland Security building and area monitoring, 1st Responder hazard determination, agroterrorism assessment, airport monitoring, and Civil Support Team actions.

c. Commercial: Clinical diagnostics, food and beverage monitoring, water analysis, and environmental monitoring.

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KEYWORDS: unmanned aerial vehicle (UAV), point detection, standalone, biosensor, rapid, automated, lightweight, microfluidic, microchip, cartridge-based

A05-T023 TITLE: Heterodyne Detection for Compact Standoff Chem-Bio Sensors

TECHNOLOGY AREAS: Chemical/Bio Defense

ACQUISITION PROGRAM STATEMENT OF INTEREST: If the technology approach in the subject STTR topic is successful, it could be integrated into the Artemis standoff detector acquisition program for multiple-platform CB Defense. The technology would enhance Artemis CB detection capabilities by increasing detection sensitivity and range for fixed site and on-the-move platforms. The Program Manager for Artemis would be interested in providing non-STTR funding during or after Phase II to integrate this capability into the Artemis program.

OBJECTIVE: We are seeking novel approaches to develop and demonstrate an innovative and robust wavelength tuner with a compact CO2 laser configured with coherent heterodyne detection for detection of chemical aerosol and vapor clouds at ranges of at least 5 km. Validate with a suitable laboratory system consisting of lock electronics and a local oscillator.

DESCRIPTION: Innovative and creative approaches to this research and development effort are requested to establish and validate a CO2 wavelength tuner applicable to both fixed site and on-the-move detection of airborne chemical vapors and CB aerosols by coherent heterodyne techniques. This effort directly supports both short-range and long-range goals for Contamination Avoidance, specifically in the Artemis, Joint Biological Standoff Detection System, Joint Surface Contamination Detector, Joint Service Wide Area Detector, Joint Decon Visualization System programs, and Future Combat Systems (FCS).

Significant flexibility is allowed in formulating proposed approaches to meet these goals. Identification of chemicals in the atmosphere by direct detection has been vigorously pursued over the last two decades, resulting in development of several test sensors with field test results reported in the literature. Aerosols have been found to represent the most challenging target, because relatively high pulse energies are required to achieve acceptable return intensities. In order to significantly increase sensor range, to reduce overall system size and weight, and to allow for incorporation of other transmitter types such as waveguide CO2 lasers, it will be necessary to explore coherent heterodyne detection. A coherent system must be wavelength agile which requires a specialized wavelength shifter and lock loop electronics to recapture system lock under a wavelength shift. To support on-the-move detection, the system must be robust and it must have a high enough pulse rate to allow for rapid scene scanning, which imposes further requirements on the tuner and lock loop electronics bandwidths. The system must be capable of further development to meet military environmental requirements.

Aerosol detection will require a wavelength tuner that can span the entire CO2 laser spectrum from roughly 9.2-10.7 mm. The traditional method of achieving such wide band coverage has been the angle tuned grating attached to a galvanometer. Such tuners can represent a large part of the laser subsystem size and weight, depending upon details of the actuation and readout mechanisms. Tuners can also be susceptible to shock, vibration, and temperature excursions. A new tuner design is required that addresses these problems of size, weight, and robustness.

Heterodyne detection requires precise locking of a transmitter laser with respect to a local oscillator. This is achieved by matching the effective resonator lengths of the two lasers. Under a wavelength shift of both the power transmitter and local oscillator, the cavity lock is interrupted and must be recaptured within an interpulse period. This will require specialized lock loop sensors and electronics. It is unknown how quickly lock can be reestablished after a wavelength shift, which will determine the maximum system pulse repetition rate, data capture rate, and scene scan rate. This a major consideration for system performance.

It is of interest to reduce overall sensor system size and weight of which the laser transmitter is a large fraction. It is of interest to reduce the transmitter size. Under consideration are compact CO2 TEA lasers and CO2 waveguide lasers. Both types have relatively low pulse energies, considering direct detection of aerosols; but they could be acceptable in the case of heterodyne detection. Laboratory demonstration of a heterodyne system based on one or both of these laser types is required.

The results of this effort will be applied in the near-term to the Artemis acquisition program to enhance its CB detection capabilities on the multiple platforms for which it is being developed.

PHASE I: Phase I will be directed to analysis and design of a robust CO2 laser wavelength shifter, a fast heterodyne lock loop, evaluation of the TEA and waveguide CO2 laser as the power oscillator, and evaluation of alternative local oscillator lasers for application to on-the-move aerosol detection and identification.

PHASE II: All efforts are to be directed toward laboratory demonstration of a CO2 wavelength shifter and potentially compact CO2 laser heterodyne detection system. A fast lock loop must be demonstrated that can support rapid scene scanning, preferably with a pulse repetition rate of at least 200 Hz.

PHASE III DUAL-USE APPLICATIONS: Phase III military applications include optimized full-sized and miniature standoff CB detectors for contamination avoidance and decontamination. In addition, dual-use intelligence and homeland defense applications could directly benefit from having a standoff detection device with optimized performance. Phase III commercial applications include spin-off detectors for standoff environmental pollution monitoring and for drug interdiction.

OPERATING AND SUPPORT (O&S) COST REDUCTION (OSCR): Compact and robust coherent sensors that utilize lower power lasers will have increased capability with more reliability and faster response time. Increased capability will encourage deployment and acceptance of new and improved detection technology. Increased reliability will reduce the burden of O&S resources. Faster sensor response times will give timely results regarding the presence of CB agents which will reduce O&S and manpower costs associated with waiting for results of questionable accuracy. The availability of instantaneous and reliable results will also reduce the manpower and time required to perform inspections of potentially large contaminated areas.

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KEYWORDS: chemical, biological, detection, LIDAR, standoff, coherent, heterodyne, carbon dioxide laser

A05-T024 TITLE: Smart Adsorbents for Chemical and Biological Protection

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: The objective of this project is to develop multifunctional smart adsorbents for protection against chemical and biological (CB) agents that exhibit extensive adsorption capacity and CB specificity and selectivity.

DESCRIPTION: The current standard material for adsorption of Chemical and Biological (CB) Agents is high surface area activated carbon (AC). The protective ability of AC is enhanced when it is surface modified with special metal salts and organic compounds. The chemical agents that are adsorbed onto activated charcoal are copper oxide, silver salts, cobalt (VI) salts in ASC Whetlerite Charcoal adsorbents. Due to the toxicity and carcinogenicity of Co, Zn salts are replaced for Co salts in ASZ impregnated charcoal. Surface modified AC has been used since WWII with little change. However, there have been many technological and materials developments in the ensuing years that can contribute to a quantum jump in protective equipment efficacy, efficiency, and effectiveness if they can be cost effectively developed and integrated into CB protective equipment such as gas masks and protective clothing. Some of the promising technologies include:

1. Metal oxide or ceramic based adsorbents that possess high specific surface areas and strong adsorption capacities for CB agents.
2. Nanophase materials with the ability to "destructively adsorb" CB agents (i.e., decompose the CB agents into less toxic forms.
3. Molecular imprint materials (MIMs) based on polymers (MIPs) or ceramics (MICs) that can be specifically targeted for CB agents based on template technologies.
Research efforts that focus on exploring these and related technologies and adapting them for CAB protective equipment will be instrumental in developing the next generation of smart adsorbents and protective gear for CB agents.

PHASE I: Evaluate the potential and feasibility of adapting existing technologies such as destructive adsorbents, high surface area ceramics, molecular imprint materials (ceramics, polymers) and/or hybrid technologies to provide enhanced protection against CB agents.

PHASE II: Incorporate the next generation CB adsorbents into protective masks and clothing and perform benchmark tests that provide data regarding system performance under the most strenuous exposure conditions.

PHASE III: The smart CB adsorbents and CB masks and clothing developed with them will have direct applications for protecting military personnel from CB agents. Civilian applications for this technology include protective equipment for firefighters.

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KEYWORDS: Adsorbents, chemical and biological protection, molecular imprint materials, template

A05-T025 TITLE: In-Building Acoustic Signature Identification

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop an acoustic signal analysis capability able to discern the operation and hence presence of various mechanical and electrical sub-systems within a building and give some information as to their location.

DESCRIPTION: During military urban operations it is often advantageous to gather all rapidly available information about a building and its occupants prior to entry. In the area of infrastructure reconnaissance one means of remotely obtaining useful information is through identification of acoustic signatures. An acoustic source can be obtained by laser vibrometry, the introduction of one or more wireless microphones, or by other means. This work is to presume one or more sources and develop the analysis capability to identify building sub-systems. Some examples would include operating motors, generators, compressors, fans, centrifuges, lights, and other relevant industrial equipment. The ability to approximately locate each unique source identified within the building is also a requirement of this work. However, given the associated difficulties and complication involved general directional information may be sufficient.

PHASE I: Using one or more actual, continuous acoustic data sets from within a building demonstrate the ability to both identify and approximately locate a single sub-system. Further, outline an expanded capability in detail based on accepted engineering principles of a field deployable analysis capability able to identify and simultaneously locate a large and pertinent variety of typical acoustic sources.

PHASE II: Develop and demonstrate an operational acoustic analysis prototype system using available acoustic sensors within at least three acoustically complex, operational and disparately different buildings.

PHASE III DUAL USE APPLICATIONS: This system could also be used in hostage situations as well as being easily adapted for natural disaster search and rescue applications.

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KEYWORDS: acoustic, signature, in-building, sub-systems, mechanicals

A05-T026 TITLE: Collaborative Tools for Integrated Hazard Management

TECHNOLOGY AREAS: Chemical/Bio Defense, Human Systems

OBJECTIVE: To improve the DoD's ability to respond to a terrorist attack or other disaster involving utility systems through the use of emerging research in the areas of information technology and cognitive science that allows relationships to be developed and conclusions to be drawn from non-formatted data and input from disparate stakeholders and data sources.

DESCRIPTION: The systems that provide electricity, water, and other utility services to the nation are vulnerable to terrorist attacks, natural disasters, accidents, and other situations that can cause service disruption or threats to life and safety (such as contamination of a water source). Utility systems are highly interdependent; a failure in one area or system can lead to failure in many others. For example, consider the massive 2003 power outage in the Northeastern United States. Each of the service providers involved had knowledge and data about their own specific part of the power grid and took appropriate action based on local conditions, but nobody was able to see the total picture, forecast the cascading power outages, and take preventive action. Many communities lost water service as well. During a crisis situation, decision makers' abilities to consider system-wide conditions, proactively consider changes in those conditions, and access expert knowledge and opinion are severely limited. Relevant information and knowledge is likely to be widely dispersed and/or unformatted. Sensors provide additional critical data, but it must be interpreted within the context of the situation at hand to be of value. Recent developments in sensing, information technologies, and cognitive science hold the promise to allow efficient assessment and monitoring of complex system-wide interactions by combining information from multiple sources (NSF 2003; National Research Council, 2002). It is hypothesized that emerging research in the areas of human-based genetic algorithms, human-computer innovation (such as real-time text mining and chance discovery) could be used to bridge the gaps in knowledge, make sense quickly of disparate, unformatted information and human input, and facilitate interaction between the stakeholders involved.

Due to the sensitive nature of data and conclusions drawn from the data, research must be conducted using realistic "dummy" data.

PHASE I: Develop methods and algorithms that enable relationships to be developed and conclusions to be drawn from non-formatted data, input from a variety of stakeholders, and disparate data sources in a crisis situation involving attacks on or damage to a utility system. Human-based genetic algorithms, real-time text mining, and/or other emerging research that merges cognitive science and information technology shall be utilized.

PHASE II: Incorporate the methods and algorithms developed in Phase I into a collaborative, secure, web-based computer framework that integrates data mining, modeling, visualization, multiobjective optimization, distributed collaboration, and diverse knowledge and data sources (including sensors) with the objective of assisting the team that is responding to a terrorist attack or natural disaster that has damaged a utility system. Demonstrate the system using a "dummy" utility distribution network.

PHASE III DUAL USE APPLICATIONS: In addition to DoD installations, this method could be used by a wide range of utility companies and institutions who are concerned with hazard management and disaster response.

REFERENCES:
1) National Research Council Computer Science and Telecommunications Board, Embedded everywhere, a research agenda for networked systems of embedded computers (Washington, D.C: National Research Council, National Academy Press; 2002.)
2) National Science Foundation Advisory Committee for Environmental Research and Education, Complex environmental systems, synthesis for earth, life, and society in the 21st century (Washington, D.C.: National Science Foundation, www.nsf.gov/ere; 2003)

KEYWORDS: genetic algorithms, utility systems, distributed collaboration, emergency response, data mining,

A05-T027 TITLE: Development of a Temporary Hemostatic Wound Treatment Incorporating Vitrification of Platelets and Immobilized Factors for Increased Wound Healing

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop an advanced hemostatic treatment that incorporates platelets stabilized in a glass state, along with immobilized growth factors and extracellular matrix components. The treatment will significantly control both venous and arterial hemorrhage in less than two minutes, reduce bleeding time, release platelet-derived wound healing factors in a sustained manner, and be safe to use on any soldier. Furthermore, the treatment should demonstrate an ability to release in a prolonged manner or present to the wound area factors essential for increased healing speed and functionality. Contractor innovation in treatment development will be actively encouraged. Development of such a hemostatic dressing supports several subareas of the Biomedical Technology Area Plan for Combat Casualty Care.

DESCRIPTION: Considerable progress in techniques for the management of life-threatening arterial and venous bleeding has been made recently. Furthermore, advances in the technology of blood and blood product storage have resulted in several different methods for the vitrification (placing in a glass-state) and subsequent long-term stabilization of platelets. Platelets are a critical component in the clot formation cascade vital for cessation of any damage to the vascular system, and contain numerous growth, wound healing, and hemostatic factors, and provide a matrix for clot formation and wound repair. Platelet-rich plasma (PRP) is currently used in oral and maxillofacial surgery as a gel to improve wound healing and hemostasis in bone and soft tissue grafts, as well as an alternative for fibrin glues. The utility of lyophilized platelets incorporated into a field bandage is currently being studied. The purpose of this STTR is to combine these two fields, using the existing technology of platelet vitrification incorporated into a field expedient use by a far forward medic or surgical team. The resulting treatment would be stable at operational temperatures (-30° to 150°F), would have a long shelf life, would not require special storage conditions (i.e., refrigeration), and simple to use. The product would require only the moisture of the wound area to reconstitute the platelet product and initiating clot formation. Finally, the product should demonstrate biological activity of specific growth factors and/or the incorporation of extracellular matrix proteins, proteoglycans, or glucosaminoglycans which will improve hemostasis, wound healing, and wound functionality. FDA approval of the device is critical to the success of the dressing, and the contractor will be required to demonstrate significant progress towards submission of an IND for this product.

PHASE I: Demonstrate a technique for vitrification of platelets that results in minimal damage to platelet morphology and function, while immobilizing growth and matrix factors required for wound healing. Evaluation of Phase I efficacy will be accomplished by assessing platelet morphology, biochemical status, aggregation time, and presentation of surface markers of platelet activation for reconstituted, lyophilized platelets versus control platelets, and biological assay of wound factor activity.

PHASE II: Develop a prototype hemostatic treatment that incorporates lyophilized platelets. Conduct testing with animal models of both external and internal hemorrhaging and soft tissue wound healing and demonstrate efficacy versus current hemostatic treatments.

PHASE III DUAL-USE APPLICATIONS: This product can be used in all echelons of military and civilian medical care. Any situation where serious bleeding from trauma or surgery could result in serious injury or death would benefit from the application of such a hemostatic dressing. Furthermore, literature suggests that such a product would be invaluable for application on chronic wounds.

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KEYWORDS: platelet, vitrification, hemostasis, wound, dressing

A05-T028 TITLE: Minimalist Short-Range Wearable Network for Soldier Training

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop and demonstrate a minimalist wireless short range (100-300 m) Wearable Network to support the capture and near real-time analysis of geolocation, activity, and physiology information relevant to Army instructors and physically active trainees. This enabling technology is intended to improve the safety and effectiveness of training and decrease the likelihood of environmentally-induced injuries.

DESCRIPTION: Recent field studies suggest Army instructors and their Soldier-students could benefit from wearable short-range low-bandwidth network technologies. By combining short-range wireless communications technology with appropriate body-worn sensing and classification algorithms, activity and physiology data can be captured and near real-time statistical analysis and classification performed. The resulting real-time physiological state classifiers of interest might relate to physical activity and biosignals that can help predict success/failure on achieving training objectives, to correlate objective measures of activity or physiology with subjective reporting of fatigue or alertness, or to correlate or predict other militarily or medically relevant variables. This mission-relevant task area is currently not possible due to the lack of appropriate technologies for minimalist wireless short range (100-300 m) networking of free-living individuals.

Currently, powerful wireless local area network technologies exist that might be used in the field. However, the capabilities of these systems far exceed those needed for the present task. Rather, short-range low-bandwidth wireless network technologies are sought that adhere to a minimalist philosophy of simplicity and robustness and can be used in austere Army field training environments. Novel approaches, such as the use of mesh-topology networks and distributed on-body computing with reduced size, power consumption, and bandwidth, are of interest. From a trade-space point of view, the proposed system, on one hand, can be low-bandwidth, have detectable radio-frequency emissions, and be near real-time rather than continuous and real-time, and, on the other hand, be exceptionally lightweight, low power, field expedient, simple to use, and inexpensive. The proposed approach should be scalable to larger groups and open and non-proprietary with respect to interconnectivity and use in new applications. Clearly, technical risk is involved in the path to an appropriate solution. Comparing and contrasting chosen physical and link layer (software protocol) approaches with evolving industry standards for short-range low-power systems such as IEEE 802.15 (http://grouper.ieee.org/groups/802/15) is desirable.

PHASE I: Define an overall Wearable Network architecture concept, identify planned use of commercial and custom elements, and provide detailed performance predictions for the primary performance metrics which are achievable bandwidth, concurrent channels, and energy use. Initiate mathematical modeling and computer simulation of network performance on a larger scale, proving that desirable properties of robustness and effective resource management are possible as the size of the network is scaled up. Perform proof-of-concept (bench-top) demonstration showing viability of the chosen technical approach.

PHASE II: Produce at least five (5) prototype Wearable Network systems suitable for field trials and performance measurement. This system will consist of a body-worn, sensing, computing, and wireless communications technology prototype that can be field-tested by physically active Army instructors and trainees. The Phase II effort will include field trials of the Wearable Network under various working and training conditions to determine the reliability, energy utilization, bit error rate test performance, and tolerance to the failure of individual nodes. The report documenting the technical specifications and performance of the Wearable Network will be provided along with engineering plans for ruggedization and packaging of the wearable network elements to support deployment in the Army training environments.

PHASE III DUAL USE APPLICATIONS: The offeror should aggressively pursue civilian Wearable Network applications. Robust Wearable Network technology would be useful in routine, near real-time monitoring of geolocation and health status of firefighters and emergency personnel working in harsh environments, as well as monitoring the apparent sleep state and location of sentries.

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1) http://www.usariem.army.mil/wpsm/index.html2
2) http://www.hitl.washington.edu/kb/wearotn.html

KEYWORDS: Exercise, home health care, ambulatory monitoring, wearable sensors, Warfighter Physiologic Status Monitor, Ranger Training Brigade

A05-T029 TITLE: Fatigue and Performance Modeling of Sleep Deprived Soldiers

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: Develop a biomathematical computational model to predict the impact of fatigue, sleepiness, and countermeasures on soldier performance.

DESCRIPTION: Continuous and sustained military operations (when there is little or no opportunity for sleep), produce deficits in soldiers' cognitive performance abilities that can result in inefficiencies, errors, and even death (e.g., resulting from friendly fire incidents). However, the impact of fatigue and sleepiness (which are frequently often unavoidable aspects of military operations) could be minimized if models were developed that could be used to optimize alertness and sleep/performance management. It is anticipated that such a tool would have broad applicability, used to improve performance (and thus safety) of soldiers engaged in virtually all aspects of military operations. For example, it could be applied to predict (and mitigate) periods of reduced alertness in truck drivers engaged in logistical operations. Based on a driver's recent sleep/wake history and circadian rhythms, the optimal timing and duration of rest periods (or optimal timing and dose level of pharmacological countermeasures such as caffeine) could be specified to reduce risk of motor vehicle accidents. Likewise, the cognitive performance capacity (e.g., likelihood of making a friend vs. foe identification error) of the warfighter engaged in sustained combat operations could be specified based on his/her sleep/wake history and circadian rhythms--and appropriate countermeasures recommended. Furthermore, the 'recycle rate' of soldiers engaged in combat operations could be specified (i.e., how much between-missions rest is needed to restore performance capacity to 100%).

Recognizing the need for such a tool, a recent international workshop (co-sponsored by the Department of Defense) was organized to assess the state-of-the-art of biomathematical models of fatigue, sleepiness, and performance; identify conceptual and technological barriers to these models; and identify and communicate research needs in military and civilian applications [1]. One of the key findings of the workshop was that each of the current models is ultimately a derivative of the two-process model of sleep regulation proposed by Borbely in 1982 [2]--which is itself a model of sleep regulation—not a performance prediction model. Accordingly, similar deficits in the ability of each of the currently existing models to predict human performance and assess accident risk (goals of the workshop) were evident.

Another finding from the workshop was that previously identified [3,4] critical gaps in fatigue and performance research remain unaddressed. In particular, there is a need to develop models that:

1. Predict individual performance (in addition to group-average performance);
2. Provide quantitative, objective statements of the reliability of the model predictions, such as statistical error bounds in the form of standard error, confidence intervals, and prediction intervals;
3. Are systematically validated and quantitatively characterized so that it can be determined, a priori, to what set of scenarios/conditions the models are applicable and where they are inadequate/fail to accurately predict performance;
4. Predict the effect of performance-enhancing and wake-promoting countermeasures, such as prophylactic naps, caffeine, and other fatigue countermeasures.
5. Make use of performance metrics (i.e., model outputs) that have close ties to real-world, military relevant mission activities as opposed to simple response-time metrics, such as the commonly used Psychomotor Vigilance Task (PVT).

This solicitation seeks an integrated research plan that addresses at least one of the research gaps identified above and follows a conventional life-cycle model development protocol where models are systematically developed, validated, and refined to provide a comprehensive explanation of the underlying mechanisms of the observed phenomenon. This may include the iterative development of biomathematical models coupled with experimental laboratory/real-world validation tests. This solicitation does not seek minor refinements of existing models by the incorporation of additional model components or fitting of model parameters so that the differences between predicted and observed values are minimized for one particular experiment without really improving model generalization capabilities where new, unanticipated scenarios/conditions can be accurately predicted. Rather, it is soliciting innovative ideas [5] necessary to address the research gaps outlined above. The government will provide some existing experimental data.

PHASE I: Conceptualize a comprehensive research plan, including model development, refinement and validation tests as well as corroborating laboratory/real-world experiments that address at least one of the research needs identified above. Conceptualize and develop early software prototype that demonstrates proof-of-feasibility of the proposed approach. For example, to incorporate the effects of countermeasures one could: (1) identify the required experiments, (2) attain results from already performed laboratory experiments, (3) propose additional experiments, (4) identify a robust computational framework for model development, (5) identify systematic model validation tests, (6) identify performance metrics, and (7) provide an indication (based on early prototype, readily available data or open-literature results) that the proposed modeling framework has sound development and investment potential. The goal of the Phase I effort is to perform the necessary research to demonstrate proof-of-feasibility of the proposed approach.

PHASE II: Extend the concepts developed during the Phase I effort. Perform laboratory/real-world experiments as needed to develop fully operational models. Perform comprehensive model validation tests. Phase II deliverable should be a fully developed and demonstrated model (e.g., that could loaded onto and run on a laptop computer).

PHASE III DUAL USE APPLICATIONS: Sleepiness and fatigue—and the errors, inefficiencies, and accidents that result from sleepiness and fatigue—are significant problems in both the military and civilian operational sectors (e.g., sleepiness has been estimated to cost the US economy $90 billion per year). The proposed model development effort would produce a set of computational tools that could be used to mitigate the effects of sleep loss in shift workers, emergency workers (firemen and police), medical personnel, and anyone else involved in 24-hour-per-day operations, or who remains available to respond on an “on-call” status for extended periods. The Phase III effort shall include thorough validation of the algorithms with real-world operational performance data.

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KEYWORDS: sleep and performance model, operational performance prediction, alertness management

A05-T030 TITLE: Develop an Innovative Method to Optimize the Kevlar Helmet Design Using 3D Imaging Techniques

TECHNOLOGY AREAS: Ground/Sea Vehicles, Biomedical

OBJECTIVE: Determine and implement optimal parameters for improvement of Kevlar helmet design to minimize traumatic brain injury.

DESCRIPTION: Protection from exacerbated injury in response to impact of the Kevlar helmet could be mitigated by varying a number of parameters including increasing the offset distance of the helmet, increasing the thickness or varying the composition of the helmet. Improvement in helmet design to lessen injury upon impact would benefit from animal models to determine the best modification of parameters to reduce injury. A well-established blunt trauma model (Chen et al., 1996) in anesthetized mice, using a precisely-calibrated weight drop device, could be used to establish parameters that induce minimal injury. Using a micrometer-calibrated frame, a firmly-supported sheet of uniform-thickness Kevlar at precise distances above the mouse skull, to absorb the impact of the blunt trauma. In this manner, optimal offset distance for a given thickness and grade of Kevlar could be determined. Such a model would offer the advantages of being inexpensive, permitting high-throughput and affording histopathological validation. Degree of protection would be determined by examination of the skull and histopathological examination of the brain, and confirmed by cognitive measures of performance. Although the

geometry as well as the size of the rodent skull differs from that of the human skull, new technologies would permit using data from the relatively planar rodent model of CHI, to scale up to model a larger skull with more complex, more spherical, geometry. Novel technology for 3-dimensional imaging of the human head could be combined with the technical capabilities to use data from a planar model to optimize offset distances and fit for any size or shape of skull, for a range of impact force parameters and for any given thickness of Kevlar.

PHASE I: Design an appropriate 3D imaging system for human head reconstruction and helmet design. Conduct preliminary study on parameters of optimal offset distance for a given thickness and grade of Kevlar in animal model of closed head injury.

PHASE II: Finalize and implement the 3D imaging system design. Scale up to model protection from injury in a larger skull with more complex, more spherical, geometry using novel technology. Use data from a planar model to optimize offset distances and fit for any size or shape of skull, for a range of impact force parameters and for any given thickness of Kevlar.

PHASE III: While improvement of Kevlar helmets is primarily of military importance, improved helmet design and information obtained regarding optimal parameters to protect the head against injury could also be used to improve design of helmets used by football players, bicyclists, racetrack drivers, police, and others. In fact, the realization of the need for improving helmet design used by football players has recently received a lot of media attention, for somewhat similar reasons as described above.

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KEYWORDS: 3-D imaging, Kevlar, Helmet design, TBI, traumatic brain injury, closed head injury, CHI

A05-T031 TITLE: Novel Routes of Drug Administration to Enhance Compliance in Soldiers

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The objective of the topic is to develop an approved transdermal device to prevent malaria and save lives by enhanced compliance.

DESCRIPTION: Malaria is a major infectious disease threat to U.S. forces deployed worldwide and can rapidly incapacitate large numbers of personnel. Our recent experience in Liberia exemplifies the problem. Of 290 troops who stepped ashore there, 80 developed malaria (28%), and 69 of the 147 who spent at least one night ashore acquired it (44%). Five of these marines required intensive care unit support. We are fortunate no lives were lost. Incomplete compliance with malaria prevention medication was determined to be the cause of the problem. Antimalarial prophylaxis has two common and important limitations: non-compliance with dosing and minor side effects (e.g., gastrointestinal intolerance). A weekly-applied transdermal medication would substantially resolve these two major drawbacks. Moreover, antimalarial drugs with inadequate oral efficacy, candidates with first pass/intestinal metabolism, or acid instability may achieve acceptable efficacy via this novel route (e.g., azithromycin). Transdermal medications have been in clinical use for many years. Such products include nitroglycerin, estradiol, clonidine, fentanyl, nicotine, scopolamine, and estradiol. Each year, the technology to deliver more challenging molecules is improved. As yet, no antibiotics or antiparasitics are available (or are being developed) for delivery by this unique route. Antimalarial drugs have lipophilic properties that make them good candidates for transdermal absorption. Klayman and colleagues first showed that antimalarials could have transdermal activity with artemesinin derivatives in mice (6). Transdermal primaquine has also been shown to have causal prophylactic activity in mice (7, 8). Both transdermal primaquine (5) and doxycycline (9) have sufficient flux across cadaver skin to predict that therapeutic plasma drug concentrations will be achievable in clinical use. Studies with transdermal erythromycin suggest that therapeutic concentrations should be achievable (3), suggesting that this route may also work for azithromycin. Drugs are also commercially available and hormones are administered via

subcutaneous implant (1, 2, 4). It is possible that drugs of importance to the US military could also be administered in this fashion. It is generally accepted in the medical community that the less frequently a drug is dosed, the higher compliance is. The two most relevant references compare oral versus transdermal contraceptives in randomized controlled trials. The patch versus oral contraceptive efficacy was 94% vs 74% ($p < 0.001$) in the first trial and 88% vs 78% ($p < 0.001$) in the second (10, 11). For military purposes, monitoring of the presence or absence of a patch would be much simpler than monitoring of daily or weekly dosing of a medication.

PHASE I: Identify appropriate antimalarial drugs and innovative technologies for drug delivery. Perform initial assessment of pilot patches using standard pharmacological methodologies (e.g., transdermal flux, pharmacokinetics, animal efficacy) to select optimal delivery technology for specific antimalarial drug classes using currently available drugs. Examples of possible drugs for testing include primaquine, doxycycline, azithromycin, atovaquone-proguanil, methylene blue, desbutylhalofantrine, and artemisone. The following must be presented at the end of Phase I: feasibility of a weekly or less frequent administration, plan for FDA approval, plan for proof of efficacy and dose feasibility, and plan to assess stability in tropical environments for a minimum of 2 years. Collaboration with institutions with experience in the development of antimalarial drugs and drug development is strongly encouraged.

PHASE II: Select lead drug candidates, perform proof of concept in clinical trials.

PHASE III DUAL USE APPLICATIONS: Perform clinical trials that will lead to approval of a new FDA-approved malaria prevention product. A protective efficacy of 85% with a lower confidence interval of 70% is the minimum standard, with 95% with a lower confidence interval of 80% is desired. Dual Use: Antimalarial prophylaxis is required by soldiers and civilians traveling to areas of risk. Civilian use of the invention, if successful, should be profitable.

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KEYWORDS: implant, transdermal, drug, drug delivery, compliance, adherence, antimalarial, drug development, life-saving, military, soldier, malaria, Liberia, special operations

A05-T032 TITLE: Robotic High Intensity Focused Ultrasound (HIFU) Manipulator System for Critical Systems for Trauma and Transport (CSTAT)

TECHNOLOGY AREAS: Biomedical

ACQUISITION PROGRAM: FCS

OBJECTIVE: Design and prototype a robotic manipulator capable of closed-loop or tele-operated control of a High Intensity Focused Ultrasound (HIFU) active hemostatic device as part of the Army's Critical Systems for Trauma and Transport (CSTAT) for future implementation on the Future Combat Systems (FCS) Medical Treatment and Robotic Casualty Evacuation Vehicles. HIFU technology is potentially capable of detection of hemorrhage and cauterization of internal or external tissue in combat casualties without antibiotics or surgery.

DESCRIPTION: The purpose of this research topic is to prototype a ruggedized High Intensity Focused Ultrasound (HIFU) active haemostatic device for field combat casualty care and integrate that device with the Life Support for Trauma and Transport (LSTAT) system (Refs 1-3) via a robotic manipulator and closed-loop or tele-operated control mechanism for future implementation on the Future Combat System (FCS) and Joint Robotics Program (JRP) Family of Integrated Rapid Response Equipment (FIRRE) Medical Treatment and Robotic Casualty Evacuation Vehicles. Previous research efforts have produced a non-rugged prototype self-contained HIFU unit which could be used to detect bleeding and cauterize internal or external tissue without the need for antibiotics, surgery and in some cases anesthesia (Ref 4). HIFU has a distinct advantage over existing cauterization techniques, such as electrocautery and lasers, because it can deliver energy deep within the body without damage to intervening tissue, and potentially from outside the body. Though not yet cleared by the FDA, preliminary results have shown that HIFU can occlude blood vessels, stop bleeding from hepatic and spleen injuries, and arrest hemorrhage from injured capillary beds and major blood vessels (Ref 5). Because of its versatility and therapeutic value, it is highly desirable to accommodate a ruggedized HIFU unit in the Next Generation LSTAT (NG-LSTAT). The immediate challenge is to prototype a ruggedized HIFU capability with a robotic arm that can be remotely operated. Some of the inherent research challenges associated with implementing robotic or telerobotic control of combat casualty care instruments on the LSTAT include data communication interfaces, bandwidth, latency, power fluctuations, platform stability, imaging and visualization, and patient/robot registration and positioning accuracy.

Background. Battlefield medicine is moving toward adoption of several new technologies to both improve the quality of care and protect healthcare providers. With advances in medical technology, secondary and tertiary care is moving closer to the point of first response. One example of this trend is use of the LSTAT patient transport litter in combat conditions of Kosovo, Afghanistan, Southeast Asia and Iraq, where LSTAT devices have been field tested by the Army. With its integrated patient monitoring and life support capabilities, LSTAT represents state-of-practice in battlefield medicine allowing patients to be cared for with less direct attention by medics during transport to field medical facilities. FCS doctrine provides for small units of action with embedded medics and medical teams. Since these units of action are capable of rapid movement over wide areas of terrain, the Army has documented a requirement for a lighter LSTAT type device called a CSTAT (Critical Care System for Trauma and Transport). While LSTAT is a particular device; CSTAT is the capability. Likewise the Army Medical Research and Materiel Command in cooperation with DARPA, the Army PM Force Protection and the JRP FIRRE Integrated Product Team (IPT) have initiated long term programs to leverage emerging robotic technologies to assist in or perform casualty location, assessment, treatment and evacuation. Osborn and Rocca (Ref 6) looked at salient issues regarding research needed for the NG-LSTAT. They concluded that robotics is a key enabling and force multiplying technology because it alleviates some medical expertise requirements on the part of caregivers and allows care by experts from a distance. With the increasing probability of operations in urban or contaminated environments, it is likely that robotics will play an increasing role in combat casualty care of the future. At some point, secondary and tertiary robotic interventions will occur while the patient is still on a CSTAT type device. This research topic is a step in that direction.

PHASE I: Design a robotic manipulator capable of closed-loop or tele-operated control of a High Intensity Focused Ultrasound (HIFU) active haemostatic device and a feasibility concept for implementing a prototype on the Life Support for Trauma and Transport (LSTAT) system.

PHASE II: Develop and demonstrate a prototype High Intensity Focused Ultrasound (HIFU) active haemostatic device operated by robotic manipulator using closed-loop or tele-operated control.

PHASE III: Conduct clinical trials and obtain FDA approval for use. Assist with implementation of the robotic HIFU manipulation system on the Next Generation LSTAT or CSTAT and with transition to the Future Combat Systems Medical Treatment and Evacuation Vehicles. Coordinate with civilian emergency first responders and Homeland Security agencies to transition the capability to dual use in hazardous or contaminated environments or in remote medically underserved areas. Transition the system to civilian police, fire, and medical first responders through ongoing USAMRMC TATRC administered civilian first responder programs such as the Center of Excellence for Remote and Medically Underserved Areas (CERMUSA) Robotic Emergency Medicine & Danger - Detection (REMED-D), the National Bioterrorism Civilian Medical Response Center (CiMeRC), and the Texas Training and Technology for Trauma and Training (T5).

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KEYWORDS: Hemorrhage, cauterization, ultrasound, hight intensity focused ultrasound (HIFU), Life Support for Trauma and Transport (LSTAT), Critical Systems for Trauma and Transport (CSTAT), robot, combat casualty care, telemedicine