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 2003 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 organizations 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, a firm may be invited to propose Phase II. Note that under the new Congressional Reauthorization for the STTR Program, any Phase II contracts following on Phase I proposals submitted under this solicitation will be limited to a maximum of $750,000 over a period of two years. Contract structure for the Phase II contract is at the discretion of the Army's Contracting Officer after negotiations with the small business.

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 3.4n 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 2003 STTR TOPIC DESCRIPTIONS

ARMY03-T01 TITLE: The Virtual Observer/Controller (O/C) --- Intelligent Coaching in Dismounted Warrior Simulations

TECHNOLOGY AREAS: Human Systems

ACQUISITION PROGRAM: USAIS, Combined Arms Tactics Directorate

Objective: Develop intelligent, automated coaching and feedback for training dismounted small unit leaders and teams within a collective virtual simulation/computer gaming environment. The intent is to merge two training technologies – intelligent tutoring engines for individual skill training and virtual/gaming simulations for small-unit, dismounted operations. A synthetic, intelligent observer/controller (O/C) shall be created within simulations to perform the real-time coaching and feedback functions similar to those functions executed by actual O/Cs or unit leaders during field exercises within a unit or at the Army's Combat Training Centers.

Description: The Army has invested considerable resources in developing simulations for small-unit dismounted warrior operations. Recent advances in technology have provided the necessary resolution and detail in the terrain needed for dismounted operations. In addition, considerable progress has been made in realistically displaying human behavior. Nonetheless, the training effectiveness and value of such simulations continue to reside in the expertise of the individual trainer. This trainer establishes the rules for the exercises, watches how the unit executes a scenario, and then provides feedback. The trainer typically decides which exercise segments to replay and what results to display. In live, field exercises, the trainer or observer/controller (O/C) not only provides the after-exercise feedback, but also coaches during the exercise, to include stopping the exercise if necessary. The purpose of the proposed effort is to integrate intelligent tutor computer engines used for individual skills with collective simulations of small-unit dismounted operations in order to embed the warfighting expertise of "live expert coaches" in the simulation. The merger of these technologies would mean that the training value of the simulation would not be as highly dependent on the training and military expertise of a single trainer. Also by incorporating such expertise there is some guarantee that the simulation exercise will result in the desired training objective, not simply be an event or a "game." Dismounted warrior operations also require that intelligent tutor engines be modified to accommodate the "unbounded" nature of such operations, where there can be multiple means of accomplishing the mission, rather than just one solution.

Phase I: Phase I shall consist of a front-end analysis to determine the missions or collective tasks to be simulated, and identification of suitable measures of performance and effectiveness. The tasks shall be basic, dismounted Infantry unit collective tasks, that represent differing degrees of uncertainty regarding how the tasks are best planned and executed. The task domain shall be at the small-unit level. An approach shall be developed for modifying current intelligent tutoring engines to incorporate feedback at the collective level as well as feedback to individuals. In addition, the engine shall be modified to provide feedback that accommodates multiple solutions to a problem. Requirements for providing coaching during an exercise and feedback following an exercise shall be determined. The performance data to be collected and stored during the simulation shall be determined and a means of transferring it to the intelligent engine identified. Virtual scenarios that accommodate the tasks to be trained shall be identified/modified. Subject matter experts shall be interviewed and training and doctrine manuals reviewed to determine the knowledge base required by O/Cs for at least one of the selected tasks. The proposed solutions for creating a synthetic intelligent O/C within a small-unit dismounted warrior virtual/gaming simulation environment shall be documented in a Phase I report. The report shall also include findings from the front-end analysis of the collective tasks to train, documentation of simulations available for these tasks, measures of performance, simulation database requirements, the expert knowledge database required for the selected task(s), and modifications required to intelligent tutoring technology.

Phase II: In Phase II, the synthetic intelligent O/C virtual training/coaching simulations agreed upon in Phase I shall be developed. A milestone schedule for generating the "intelligent O/C engine," determining the individual and collective behaviors to assess, and merging this capability with virtual dismounted simulations and scenarios shall be established. Three dismounted warrior mission/tasks shall be used. Assessments of the effectiveness of the training products as well as reactions by soldiers and leaders shall be conducted simultaneously with product development. An assessment plan shall be written for review and approval. A report describing these findings as well as the algorithms for the intelligent virtual O/C shall be produced.

Phase III: The Department of Defense and many corporations now use virtual simulations for leader and team training. The training capabilities described in this proposal apply to these virtual multi-person simulation capabilities. Incorporating a synthetic trainer that provides real-time coaching and performance feedback will result in enhanced team training, and a capability that is less reliant on quality instructors. In addition, a synthetic trainer that adapts to multiple, yet suitable solutions for accomplishing mission objectives developed by teams greatly expands the settings in which intelligent agent technologies can be applied.

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KEYWORDS: Intelligent tutors, virtual simulations, computer gaming, dismounted operations, team training, intelligent feedback, after action reviews

ARMY03-T02 TITLE: <u>Advanced Computational Algorithms for Nonlinear Filtering for Real Time Environment</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The objectives of this STTR are to investigate numerical methods for computing infinite-dimensional nonlinear filtering equations and to develop algorithms and computer software that can be implemented for military and commercial applications in real time environment.

DESCRIPTION: It has been proven that the technique of linear filtering developed by Kalman and Bucy in the early 1960's has contributed tremendously in missile guidance and modern radar technology for target tracking, etc. However, due to the complexity and non-linearity of the noisy environments and physical systems from which the real signals are to be extracted and/or estimated, the linear filtering can only serve as a first order approximation to the infinite-dimensional nonlinear filtering problem in which the signal process is described by a general nonlinear stochastic differential equation and the observation process is a nonlinear functional of the signal process corrupted by another independent source of random noise (e.g. [1], [7]). While some works have been done in numerical approximations of nonlinear filtering problems (e.g. [2,3,5,6,8,9]) all the results obtained to date are restricted to additive noise case only and there is no evidence of effort in developing software for nonlinear filtering problems with signal dependent drift and diffusion. To further improve radar technologies and image and signal processing (e.g. [4]) and to enhance effectiveness of military and commercial communication networks, it is imperative that 1) the various temporal and spatial discretization techniques and their convergence to the infinite-dimensional nonlinear filtering equations be investigated; 2) efficient numerical methods and their algorithms be developed for computing the nonlinear filtering equations; and 3) prototype computer software for the algorithms be developed for military and commercial applications in real time environment. In order to transfer the technology for commercial use, it is suggested that business technical staffs and university researchers be involved in both the investigation of the numerical methods and the development of the software. It is proposed that the program be carried out in the following three phases.

Phase I: In Phase I the following shall be accomplished:
a. Research and development of new numerical methods for computing solutions of general nonlinear filtering problems.
b. Establishment of convergence results for the numerical approximation methods with temporal and spatial discretization for the methods obtained above.
c. The analyses of error bounds and convergence rates of the numerical approximations.
d. Development of new algorithms that are suitable for real time parallel and/or distributed computing environment.

Phase II: In Phase II,
a. Computer coding of the algorithms developed in Phase I shall be done. The STTR awardee(s) shall have the flexibility of using any programming languages that deem appropriate in the development of the prototype software.
b. Statistical methods such as maximum likelihood estimators shall be employed to identify and estimate the parameters involved in both the state and observation equations that may be specific to real world applications.
c. The awardee(s) shall demonstrate the feasiability of the prototype software for a variety of commercial applications.

Phase III (Dual Use Commercialization Potential): This project involves an area of research that is important to Army and commercial community. Successful development of the advanced computational algorithms and software in real time environment will enable more accurate and faster detections and/or estimations of signals in the noisy and nonlinear real world environments and hence will significantly improve current commercial and military radar technologies and communications systems. In order to complete the technology transfer, the commercial release of the software developed in Phase II shall be authorized by appropriate DoD agency (or agencies). The awardee(s) shall have the sole copyright of the software and shall have the responsibility for the commercialization of the products.

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KEYWORDS: nonlinear filtering, numerical methods, stochastic differential equations, noise and signal processes, image and signal processing, target tracking, control and communications systems.

ARMY03-T03 TITLE: Development of Advanced Computational Algorithms for the Virtual Testing of Military Systems for Survivability and Design Studies

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM:

OBJECTIVE: Develop a robust, scalable, fully-Lagrangian, adaptive computational capability for the simulation of complex weapon/target interactions.

DESCRIPTION: One component of the Army’s Future Combat System (FCS) will be survivability of systems due to blast and high velocity impact by K.E penetrators. In addition, increased homeland security concerns have created a critical need for the design of structures with improved survivability against airborne weapon systems. Advanced scientific computing appears as a viable technology for establishing the effectiveness of such designs rapidly and accurately.

Many of the presently established codes have fallen behind in critical areas such as contact, fracture, and fragmentation algorithms, which have emerged from the University environment and whose feasibility has been successfully demonstrated [1]. More importantly, the legacy codes lack the design required for the effective implementation of advances in such areas, and have therefore become developmental dead ends. There is, therefore, a critical need for ushering in the next generation of commercial-grade scalable software informed by the latest advances in virtual test facility based on advanced computational mechanics and visualization capabilities. This will provide the capability of carrying out end-to-end simulations of complex weapon/target interaction events towards the urgently needed survivability design and analyses of potential systems for the FCS and Objective Force.

Owing to difficulties in robust three dimensional mesh generation algorithms, which must be repeatedly used during the course of the simulation as a means of eliminating deformation-induced mesh distortion, the fully-Lagrangian simulation paradigm has failed to deliver its promise of becoming the approach of choice for the next-generation of Army penetration mechanics simulation codes. Practical implementations of automatic three dimensional mesh generation algorithms [2] have been developed which have been very successful in applications where the grid does not require frequent changes. However, these algorithms lack the robustness necessary when they are used in a Lagrangian context when they are typically invoked millions of times for a single computation. Over the last few years, there has been significant progress being made in the development of algorithms that have provable performance characteristics [3]. There has been substantial headway made to close the gap between theory and practice in three dimensional mesh generation, creating the opportunity to create a robust, scalable, Lagrangian, adaptive, computational capability.

PHASE I: The research will demonstrate the feasibility and usefulness of the proposed modeling approach through a limited proof-of-concept study. The study should address an Army relevant problem in ballistics and provide comparison to existing available experimental data.

PHASE II: The research and methods demonstrated in Phase I will be further developed to produce a simulation framework suitable for predicting penetration environments resulting from weapon-target interactions.

PHASE III DUAL USE APPLICATIONS: This project involves an area of research of great interest to both the Army and the industrial community. The military end products and processes resulting from this activity will be models capable of accurately simulating the effects of conventional weapons on hardened and non-hardened structures. Advances in this field would have impact on the industrial community's ability to assess the effects of accidental explosions or sabotage in mines, storage facilities, and conventional urban structures.

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KEYWORDS: Finite element method, Lagrangian formulation, computational mechanics, mesh generation, fragmentation, impact, penetration

ARMY03-T04 TITLE: Augmented Actuation Devices for Adaptive Structures

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop and demonstrate low cost, high performance, innovative active material based actuation devices and their associated driving electronics and control systems for applications, such as structural damping, structural shape change, precision pointing, and/or vibration isolation.

DESCRIPTION: In many commercial and military systems, particularly air and land vehicles, the relative deformation of the structure and mechanical elements is a principal source of limitations on operational performance. This structural flexibility leads to vibration, interior and exterior noise, and control problems during operation, especially at high operating speeds, even though lightweight and stiff materials such as advanced composites may be used in their construction. Much progress has been made in recent years in the introduction of active (smart) materials in actuator design for force transmission and/or induced strain in these systems. The use of piezoelectric actuators, for example, to twist a helicopter rotor blade or to operate a trailing edge flap at 40Hz to produce an angle of rotation of $\pm 8°$ has fallen short of expectations. Conventional piezoelectric ceramics have proved woefully inadequate to provide the required levels of stroke and/or force. This is the greatest barrier to the introduction of active materials to produce greatly improved rotor systems that feature increased fatigue life and reduced blade-vortex interaction noise. New and promising high actuation strain materials have recently appeared or are currently under development; these include relaxor ferroelectric materials, alkaline based single crystal piezoelectric fibers, ferromagnetic shape memory alloys, etc. In the near future, application of the concepts of nano-technology to certain classes of electroelastic materials may lead to the development of actuation materials with improved physical properties. Successful use of such new actuators will depend upon the cost of manufacturing and the ease of system integration and/or retrofitting.

PHASE I: Concrete designs of novel actuators, which can deliver significantly augmented force and/or stroke relative to conventional actuators, and their associated drive electronics and control systems are expected. These designs should be scalable and easily retrofitable for a variety of applications. Their performance is to be demonstrated and verified through computer simulations and experimental validations.

PHASE II: Develop a fully integrated design, test, and prototyping environment for development of high bandwidth actuators and their associated drive electronics and control systems. These actuators should be prototyped and fully tested. It is expected that these actuators and their associated driving electronics and control system will be fully developed and designed for being easily manufacturable by the end of Phase II. Furthermore, successful applications are to be demonstrated, possibly in helicopter rotor systems, rapid firing weapon systems, or missile flight control systems.

PHASE III DUAL USE APPLICATIONS: Low-cost, high-bandwidth, high authority (force/displacement characteristics) actuators are needed in both military and commercial applications. A number of commercial systems and machinery do require added low cost actuators for performance enhancement. Examples of such commercial systems are machines used in the electronics industry, such as laser lithography machines, lead-bonding machines, and inspection and probing machines. Additional commercial applications will be found in automated quality control and meteorology related machinery, and machinery for the production and testing of ultra-high quality optical components and instruments.

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KEYWORDS: smart structures, adaptive structures, actuators, actuation devices

ARMY03-T05 TITLE: <u>Short-Range High Data Rate Wireless Communications</u>

TECHNOLOGY AREAS: Information Systems, Electronics

OBJECTIVE: Develop high data rate, short distance mobile wireless communications system, which would allow the transfer of 100's Mbps in a range of 50-100 ft from mobile base stations to combat vehicles or soldiers.

DESCRIPTION: The Army is transforming to a more responsive, deployable, and sustainable force while maintaining its high levels of lethality, survivability, and versatility. This new force, called the Objective Force (OF), is intended to meet the full spectrum of present and future Army missions. The capstone of the OF capability and the transformation is the Future Combat Systems (FCS) Program. This reconfigurable, adaptive "system-of-systems" will provide a common baseline capability that increases the Army's ability to conduct network- and collaboration-centric warfare.

One of the key areas that will determine the success of the FCS is the ability to collect and distribute relevant information to and from forward-deployed troops. Current radio-based tactical networks are intended to meet this need, but suffer from severe bandwidth constraints when dealing with common types of data such as images and maps. However, it is possible to create small islands (50-100 ft diameter around a base station) of high bandwidth (100's of MB/s) wireless communications around certain areas of the battlefield, such as command centers in order to efficiently transfer large data files. Location and situation specific data will need to be cached at the base station, so that it is available when requested by a user passing within communications range.

One example is using vehicles as mobile base stations to create the small islands of high date rate communications in the battlefield, where dismounted soldiers can quickly receive the latest recognizance data. This application fits well with the Joint Tactical Radio System (JTRS) concept, which uses software-defined radio concept, in which the soldier radio can switch modes between the normal tactical mode and the high data rate communications mode. Another example is an infantry patrol on a peace keeping mission returning to their base camp automatically receiving the latest maps, situational awareness information, and orders, as well as uploading the latest imagery and other intelligence data collected during the patrol.

In order to make this concept work, a high data rate, short distance communications are required. Some potential technologies include optical communications, millimeter wave with directional antennas, ultra-wideband, and space-time coding. Adaptive modulation and coding may be necessary to be able to vary the data rate based on the quality of the communications channel. In conjunction with the physical layer, protocols, such as medium access control and admission control, will need to be developed for this application. Furthermore, backbone network communications protocols for data caching at the base stations must be developed. Authentication and information security are also issues if the system includes a moderate to large number of base stations and/or mobile users. Previous research in these areas exists, [1], [2], but more research is necessary in order to develop a viable approach.

PHASE I: Research and develop a proof-of-concept for a secure short distance high data rate system. This research should include investigating the current state of the art in the necessary technologies and performing the research necessary to make improvements to the existing algorithms in order to be applicable to this application. Simulations and trade-off studies should be performed in order to develop a system concept including the physical communications layer as well as the network layers and communications security. The viability of the concept should be demonstrated by analysis and simulation.

PHASE II: Design and build a prototype short-range high data rate system that demonstrates its operation. Further research and design trade-offs may still be necessary at this stage. Although integration with the military operations will not be done until phase III, interaction with Army tactical users is required at this stage to ensure the system designed will meet their needs.

PHASE III: Integrate prototype system into military tactical operations. This phase will include demonstrations in a realistic tactical environment. Continued and more extensive communications with Army is required at this point, including the JTRS, Objective Force Warrior, and MOSAIC program offices.

DUAL USE APPLICATIONS: Potential commercial application are a system that could be deployed in heavily traveled areas such as road intersections, airports, and to quickly download web files, video, email etc. This technology can also be used to download pertinent information to delivery and repair vehicles when returning to their home office, and emergency vehicles when parked at the station or at often used intersections.

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KEYWORDS: Wireless communications, high data rate communications

ARMY03-T06 TITLE: Plasma Wave Electronics

TECHNOLOGY AREAS: Electronics

OBJECTIVE: To design, build and demonstrate a new class of plasma wave electronics detectors that will enable new and unprecedented levels of sensitivity in the sensing of terahertz (THz) frequency electromagnetic radiation. The envisioned detector system should implement GaAs and GaN based High Electron Mobility Transistors (HEMTs) for the resonant and non-resonant plasma-wave detection of THz signals to demonstrate the potential enhancements to system sensitivity. The performance increases enabled through the development of plasma wave electronics will have important impact to military applications such as space/covert communications, high-speed signal processing, remote detection of chemical and biological agents and terahertz-frequency imaging of weapons and explosions.

DESCRIPTION: During the last few years, new research programs have emerged within the U.S. Army and the Department of Defense (DoD) that focused on advancing the state-of-the-art in terahertz (THz) frequency electronic technology and on investigating novel applications of THz-frequency sensing. These applications include the use of fundamental interactions of THz radiation at the molecular level for sensing and characterizing chemical and biological (CB) systems and to detect weapons and explosives. However, serious technical challenges remain to be solved to realize a robust THz technology which can also be used to enable very high frequency communications and signal processing.. Here, higher power sources, high sensitivity detectors and fully functional components (e.g., three terminal devices) need to be developed while maintaining compact packages and cost effectiveness. These challenges have motivated new research in a broad array of technology areas, which include the use of plasma-wave transistor devices (e.g., based High Electron Mobility Transistors (HEMTs), in both the detection and generation of THz frequency electromagnetic radiation. As the sensitivity of the detector technology ultimately defines the required levels of source power that must be available within active sensing systems, potential sensitivity improvements available from plasma-wave transistors could have dramatic impacts to future systems that seek to utilize the THz-frequency regime. These general issues previously motivated support for the fundamental investigation of plasma wave physics and the U.S. Army has supported research into plasma wave electronic device concepts during the last decade. Most importantly, recent data on plasma wave electronics detectors [1] show that GaAs-based and GaN-based High Electron Mobility Transistors (HEMTs) are capable of both resonant and non-resonant detection of terahertz radiation [2,3]. The resonant detectors are tunable by gate bias which is an enabler for higher level detector function. The theory [1] also predicts that such detectors should have a much higher sensitivity than more conventional terahertz detectors, such as using Schottky diodes. Hence, there is a very strong motivation to reduce this device concept to practice and demonstrate highly sensitive HEMT terahertz detectors. Here, the defined task will require contributions from the device research community and from commercial engineering institutions that possess state-of-the-art design and testing facilities. Specifically, advanced plasma device structures must be implemented within high frequency circuits with efficient coupling characteristics. Acceptable approaches might include bow tie and log antennas or the use of periodic gated structures for radiation coupling [4]. These detectors should operate in broad temperature range from cryogenic temperatures to temperatures above room temperatures to allow for field deployment.

PHASE I: Phase 1 of the program should demonstrate improved detection sensitivities of GaAs-based and GaN-based HEMTs for subterahertz and terahertz radiation in the range from 0.1 THz to 2.5 THz. This research will include both cryogenic and room temperature detection. The results should allow for the comparison of the relative merits of these two materials system for terahertz detection applications and will lead to choosing a superior materials system for terahertz detection. The detection on both fundamental and higher harmonics will be demonstrated. Phase 1 will also include the antenna and periodic gated structure design for optimum coupling of terahertz radiation. This design should include calculations that will allow for quantitative comparisons of these novel devices with existing terahertz detectors. Low frequency noise measurements will be performed for relative assessments of device reliability and operation stability

PHASE II: In Phase 2 of the program, the GaAs-based and GaN-based HEMTs for the detection subterahertz and terahertz radiation integrated with optimized antenna structures should be demonstrated. These detectors will be compared with other types of terahertz detectors (such as Schottky diodes) in terms of sensitivity, noise characteristics, stability, and light sensitivity. Their operating regimes will be optimized, and the application of these devices in systems for the identification of hazardous biological agents, for antiterrorist measures, terahertz imaging, and space and covert communication will be explored.

PHASE III DUAL USE APPLICATIONS: The technologies developed under this topic will provide a foundation for a new class of point and remote sensors and further a technology that has potential towards medical applications for the microscopic interrogation of biological characteristics and chemical function. This spectroscopic technique also has potential towards the characterization of other materials of interest such as electronic materials and explosives. The very high speed transistors developed under this effort also have implications to signal processing and communication systems.

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KEYWORDS: Plasma Waves, Electron Devices, Terahertz Electronics and Sensing Technology

ARMY03-T07 TITLE: Innovative Interaction Structures and Beam Sources for Vacuum Electronics

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Transfer results from basic research on innovative interaction structures and beam sources for lightweight, power-efficient, compact, and affordable vacuum electronic millimeter-wave power sources and amplifiers using micromachining and/or other bulk manufacturing processes. Resulting technology will be scalable to different operating frequencies, manufacturable, and relevant to civilian and military communication and radio sensing applications.

DESCRIPTION: Current vacuum electronic devices are manufactured using standard machining and assembly techniques. As design frequency increases, manufacturing tolerances produce unacceptable variations in device-to-device performance. The increasing requirement for ultra-tight tolerancing leads to excessive manufacturing and assembly costs and unacceptable device yields. This program seeks to transfer results from basic research that take advantage of the bulk micromachining technology developed for solid-state electronics and micro electromechanical systems (MEMS) applications to open the application space to much higher frequencies and leverage the economies of scale to produce affordable millimeter-wave power sources for the network-centric Objective Force. In addition, this program seeks to transition new concepts in beam/wave interaction to manufactured components that will produce devices with enhanced linearity and bandwidth, enabling high-data rate communications among large numbers of devices and systems in the electronic battlespace.

PHASE I: Analyze results from basic research on innovative interaction structures and beam sources. Demonstrate manufacturability using fabrication process modeling and simulation. Estimate potential electrical performance using multi-physics modeling and simulation.

PHASE II: Fabricate and test structures and devices developed in Phase I, culminating in a prototype demonstration of the proposers' choice. Show path to manufacturability and develop plan for technology transfer.

PHASE III DUAL-USE APPLICATIONS: Manufacture millimeter wave devices and systems consistent with the TRL and electrical performance requirements for civilian communication systems (telcom, television, and data) and military systems for the electronic battlespace. Provide test data and prototype devices to Department of Defense (DoD) labs for evaluation. Performance of the devices developed in Phase II should be thoroughly characterized, and manufacturability should be demonstrated.

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KEYWORDS: Vacuum electronics, millimeter wave, micromachining

ARMY03-T08 TITLE: Dynamic Perimeter Surveillance by Swarms of Small Robotic Vehicles

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: To develop new algorithms and software for distributed, multi-robot detection and surveillance of rapidly changing perimeters

DESCRIPTION: Technical Challenge/Background: Swarms of small mobile robots have been investigated for many tasks, including determining the perimeter(s) of area(s) with mines (while demining is taking place), chemical or biological toxins and environmental degradation [1,2]. The sensors on these robots must be able to collectively lock onto the boundary/perimeter of a phenomenon, which is defined by (a decrease in) the "density" of the phenomenon (for example, the expected lethality of mines, chem/bio agent, etc. on a distance scale determined by the activities/footprints of phenomenon and of friendly forces). Development of an algorithm to lock onto the perimeter is expected to draw on state-of-the-art methodologies from the image processing literature (density-based edge detection based on partial differential equations) [3] but proposals that have likelihood of achieving the goal of perimeter surveillance by any method are welcome. The focus here is on the algorithm for appropriately positioning the robots to "see" most or all of the perimeter and on the method by which surveillance is achieved. This effort must define and justify the cooperation among the sensors that it seeks to achieve and devise appropriate distributed algorithms for tracking the perimeter and controlling the motion of the robots. The frequency and mode (relay, multicast, broadcast, etc.) of communication between the robots will be important parameters in the algorithm.

PHASE I: This phase will consist of adapting for use by a team of mobile robots recent breakthroughs in image processing (or some other area). In this phase, one must show how the density of the phenomenon is perceived in a distributed fashion and how this distributed perception is translated into actions of individual robots that allow the robot swarm to track the perimeter as changes occur. Precise estimates must be derived on the frequency and mode of communication required between vehicles in order to achieve stability of the method under both local and global communication scenarios. At the end of Phase I, the algorithm should 1) be explicitly mapped out, 2) have been theoretically justified (not in an ad hoc manner, but based on mathematical existence and uniqueness analysis in appropriate metrics) and 3) be ready for implementation.

PHASE II: Demonstration of working algorithms in simulation and proof of concept testing. At the end of Phase II, proof of concept should be field-demonstrated with one or more vehicles interacting with a virtual array from simulation. This phase should include development of methods for improving/retaining stability in a low-bandwidth-communication scenario. Changes in perimeter topology, specifically fission of one region into multiple regions and fusion of multiple regions into one, must be allowed. Robustness of the algorithm should be demonstrated under loss of a portion of the robot team and under limited communication capabilities. Experiments must be coordinated with testing and adjustment of algorithms.

PHASE III: Demonstration on robotic swarm: Full implementation of the algorithms on swarms of tens of real robots (possibly in conjunction with simulated robots) interacting with physical targets should be carried out. On the basis of these tests, design robotic swarms of one hundred or more vehicles and carry out analysis and demonstration for determining boundaries of minefields, chemical spills, environmental problems, etc. Wide applicability to terrestrial, aerial and underwater platforms is desirable.

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KEYWORDS: Mobile sensors, multi-vehicle algorithms, PDE-based edge detection, robotic swarms

ARMY03-T09 TITLE: Hierarchical Pattern Classification Systems

TECHNOLOGY AREAS: Information Systems, Sensors

ACQUISITION PROGRAM:

OBJECTIVE: Improve automated target acquisition and tracking by fusing and organizing hierarchically collections of target classifiers.

DESCRIPTION: The mainstay of automatic target recognition (ATR) systems is statistical pattern recognition. Recent research suggests that the performance of pattern classification systems can be improved by utilizing a collection of pattern classifier algorithms and fusing the decisions. Some pattern classifiers work better in some scenarios (targets and backgrounds) than others. Therefore it appears that collections of pattern classifiers may be organized in a hierarchical way, where the organization might be dynamically modified as scenarios change to emphasize classifiers which perform better for the existing conditions. Incorporating concepts from evidence theory and/or from the weights of support vector machines may provide clues to optimal organization of the hierarchy.

PHASE I: Develop methods for building dynamically-reconfigurable hierarchical classifiers, and demonstrate such methods on realistic ATR data. This work may include new methods for design of classifiers.

PHASE II: Develop a "benchtop" prototype system, including hardware and software which will observe a scene and, when provided with supervised target cueing data, automatically develop a pattern recognition algorithm for identifying that target in those surroundings. This system may include multispectral imaging capability.

PHASE III DUAL USE APPLICATIONS: Develop a prototype missile seeker system, including an off-line training component, which may receive training data from a UAV or similar source, and which will use that information to program an on-board missile target acquisition system. Multiple civilian/commercial uses of this technology clearly exist. In addition to classification and tracking of military targets on the ground, in the air and in the water, pattern recognition systems find potential application in airport x-ray, intruder detection, even identifying possible intrusions into data networks. Additional uses include detection of chemical/biological weapons by-products, agricultural monitoring, and industrial inspection and quality control. Any general theory which improves the quality of pattern recognition system performance is useful in all these applications.

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KEYWORDS: ATR, multispectral signature, pattern classification, evidence theory

ARMY03-T10 TITLE: Membraneless Microchannel Fuel Cells

TECHNOLOGY AREAS: Electronics

ACQUISITION PROGRAM:

OBJECTIVE: Develop a compact 10-W fuel cell system that 1) utilizes a microchannel, membraneless fuel cell, and 2) includes all balance of plant auxiliaries, such as fluid moving equipment, heat exchangers, and fuel/oxidizer storage vessels. The fuel cell power system should be compact (> 1 kW/L and >1 kW/kg), energy dense (> 1kWh/kg), and supply 1 kWh of energy.

DESCRIPTION: The Army has need for high-energy, lightweight power sources for the solider. Fuel cells that use a polymer electrolyte membrane (PEM FCs) are candidates to fill these needs. Such FCs may be powered by hydrogen (either neat or produced from reformed hydrocarbon) or by direct electrooxidation of a simple hydrocarbon (e.g., methanol). In conventional FC technology, the PEM is used not only as the electrolyte but also as a physical barrier to separate the oxidizer and fuel. The PEM is an expensive component of the FC and necessitates the embedding of complex electrode structures on and within the ionic domain of the polymer at opposite faces of the membrane (i.e., the so-called membrane-electrode assembly). Recently, a novel, microchannel-based fuel cell has been reported (1) in which the inherent poor mixing of two streams introduced via a Y-shaped mixing port was utilized in an innovative manner. A fuel-rich and an oxidant-rich liquid stream were forced to flow side-by-side, and electrical power was produced from reactions occurring at electrodes embedded on opposite walls of the microchannel reactor. A separator is not required in this FC configuration because commingling of reactants by diffusional transport between the two streams in laminar flow is not an efficient mixing mechanism. In addition, simple planar-electrode structures were placed on the channel walls. Although the power density was low for the particular system discussed, the concept of a microchannel-based, membraneless FC has merit and should be explored. Issues that should be addressed include, among others: microchannel fuel cell configuration; electrode type and placement on walls defining the microchannels; fuel and oxidizer combinations with particular emphasis on those that might not be considered suitable for a PEM-based FC; utilization and possible recycling of fuel and oxidizer; etc…

PHASE I: Design, construct, and characterize a 1-W microchannel-based fuel cell that combines oxidizer and reductant of contractor’s choice (but selected within bounds of safety and cost considerations). Report polarization behavior (voltage and power density as a function of current density), measure fuel and oxidizer utilization, and discuss system concepts and scale-up issues to be addressed in the Phase II effort.

PHASE II: Using results from Phase I effort and the Objectives stated above, design, construct, and evaluate a nominal 10-W fuel cell system based upon the membraneless microchannel FC. Based on factors learned during the

Phase I effort and considerations of the total system, the power range selected for the Phase II effort may be several-fold larger or smaller than the 10-W initial target size.

PHASE III DUAL USE APPLICATION: Developments in fuel cell power sources will have immediate impact on a wide range of commercial power sources from computer power to emergency medical power supplies to recreational power uses.

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KEYWORDS: Fuel cell, microchannel, soldier power

ARMY03-T11 TITLE: Enhanced Backscattering of Electromagnetic Radiation for Target Tracking

TECHNOLOGY AREAS: Sensors

OBJECTIVE: A particular advance in Optical Science is now posed to provide a new means of discrimination and tracking of moving objects, namely the use of newly discovered variants of the classic "Glory or Halo Effect" (Ref.1) now called "Enhance Backscattering." A variant of this effect will be developed to achieve assured discrimination and tracking of targets plus robust optical communication in disturbed atmospheric conditions.

DESCRIPTION: One well-known example of "Enhanced Backscattering" arises when a traveler looks out of a window of an airplane flying over a desert and looks at the plane's shadow on the desert ground. If the traveler is correctly situated relative to the position of the sun and the direction of sighting of the shadow, he/she may see a bright halo around the immediate contour of the shadow — which may disappear abruptly as the various orientations involved change even slightly. This "Glory Effect" was not understood even by 1966 (Ref. 1) but was finally understood quantitatively from research that synergetically combined analytical theory, numerical computations, and experimental research efforts. Since then it has also been called "Enhanced Backscattering of Radiation" (Ref. 2). This deeper quantitative understanding of the phenomenon has led to a number of related effects reviewed in an extensive article (Ref. 3). In essence, one is able to "engineer" the statistical distribution of roughness characteristics of man-made surfaces such that when an electromagnetic radiation beam is incident on such a surface, the reflected or transmitted beam's divergence characteristics can be controlled. These effects have also been correlated with laser speckle patterns that such surfaces produce while in motion, thereby providing means for tracking and extracting velocity information. In addition, these can be combined with coherence control means to improve optical communication through a turbulent or an otherwise disturbed atmosphere.

PHASE I: Specialized surfaces will be made and used for "tag"ing surfaces from which enhanced backscattering of laser radiation of particular characteristics can be elicited with embedded coding means. The speckle pattern characteristics of the beam reflected from the target will be studied to extract the velocity of the target in "real" time to provide a robust means of target discrimination and tracking. The coherence properties of the laser beam will be manipulated to induce special forms of partial coherence and to derive a number of coherence related optical effects (Ref. 3). Of particular interest is further research work that is to be carried out to include partial coherence effects that arise from the transmission of laser beams through turbulent and/or obscure atmospheres. During this Phase I effort, a feasibility concept of a specialized device will be developed in sufficient detail that shows that the main goals of this effort as stated in the "Objective" above can be accomplished. That is, that target identification /discrimination plus tracking can be achieved. In addition, this must be achieved by the device in such a way that the process performed by said device cannot be discerned by any other agent/means except by said device itself while this activity is being carried.

PHASE II: Since Enhanced Backscattering can be obtained at any wavelength of the electromagnetic spectrum by the appropriate scaling of the roughness characteristics of a surface, a combination of frequencies are to be used to achieve, in effect, a multi-spectrally-fused target identification and tracking means. Recent work on left-handed media (4) will also be incorporated into the above stated enhanced backscattering effects to give additional means of channeling laser beams and encoding. Since these left-handed media also produce the inverse of the Doppler shift of normal media, their potential contribution to additional means of target tracking will be explored. Improved optical/laser communication system applications will be mapped out. During this Phase II of the effort, the feasibility concepts developed in Phase I will thus be augmented by the additional research performed in Phase II, turned into a working algorithm, and the actual physical device will be constructed and analyzed showing that the stated goals are achieved. Said device will be delivered to the Army. Marketing effort will be initiated for the civilian use version of the said device. Appropriate patent applications will be filed.

PHASE III DUAL-USE COMMERCIALIZATION: These effects will be put to use for commercial applications. A particular application is vehicle collision avoidance including velocity extraction to predict vector velocity changes of the vehicle. By using multi-spectral fusing, assured all-weather functionality with high level of confidence is to be attained.

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KEYWORDS: Multiple Scattering, Enhanced Backscattering; Enhanced Retroreflection of Electromagnetic Radiation; The Glory Effect; The Halo Effect; Laser Speckle Patterns; Speckle Pattern Interferometry; Partially Coherent Radiation; Wolf Effect; Random Gratings; Propagation of Laser Radiation through Turbulent Atmosphere

ARMY03-T12 TITLE: Biocidal Textiles for Soldier Protection and Homeland Defense

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes

ACQUISITION PROGRAM:

OBJECTIVE: This topic seeks to exploit research progress in the area of biocidal polymers immobilized to textiles (e.g. cotton, 50/50 cotton/nylon blends, and polyester) to generate a protective shell fabric for a protective suit that actively decontaminates biological species, an antimicrobial undergarment, or environmentally friendly mildewcides for cotton-based shelters. The topic goals are to functionalize biocidal polymers to create highly biocidal compounds and incorporate them into textiles via covalent fiber bonding, coatings, or new concepts for fabric treatments.

DESCRIPTION: Protection against biological weapons is a key military and civilian requirement and recent events in the U.S. and around the world have clearly reinforced this need (1). This topic seeks to combine advances in polymeric biocides with textiles to produce multifunctional biocidal materials that provide protection from specific biological agent threats, increased garment wear time, and increased lifetime for cotton-based shelter structures. Functional polymers, including dendritic materials, have numerous advantages that include having a large number of sites that can be functionalized along with controlled architectures that can be exploited to generate highly reactive biocidal compounds. The choice of polymer for functionalization will depend on many factors, including, the potency of the biocidal material toward biological species and the quantity of material required in the textile to make it effective. For this topic this choice should be consistent with being cost effective for commercial applications while maximizing biocidal activity and material performance. A variety of systems can be explored for functionalization, including quaternary ammonium compounds with dendrimers (2), polymeric biocides (3,4) and other novel approaches appropriate for this topic. When choosing the polymeric material and functionalization, consideration must be given to the potential toxicity of the biocides to humans and the environmental impact.

PHASE I: This topic proposes to investigate polymeric biocides combined with textiles. Commercially available polymers should be used rather than developing new synthetic techniques unless a cost effective synthesis is easily demonstrated. Research should focus on: (1) choosing a polymeric material that can be an effective anchor for a biocide or easily functionalized, that can be incorporated into a textile, (2) demonstrating the effectiveness of the biocide, (3) incorporating the biocidal material permanently into a textile to prevent leaching (4) characterizing the integrity of the biocide/textile material, (5) characterizing the effectiveness of the biocidal textile towards model biological species, and (6) identifying promising polymer/biocide/textile combinations for study in Phase II.

PHASE II: The most promising combinations of polymer/biocide/textile should be explored in detail during Phase II to optimize biocidal activity along with enhancing material integrity. Biocidal activity should be evaluated by testing with live species, such as gram negative, gram positive and/or spore forming species. Textile performance should be characterized and optimized by exploring the speed and universality of the biocidal response, textile durability and performance, the level of capacity of biocidal activity, including as a function of relevant environmental conditions, and the chemical stability of the functionalized polymer biocide. Methods for processing and scale up of the technology should be considered.

PHASE III DUAL USE APPLICATIONS: This topic focuses on biocidal textiles for a protective shell fabric, a protective suit that actively decontaminates biological species, an antimicrobial undergarment, and environmentally friendly mildewcides for cotton-based shelters for Department of Defense (DoD) and homeland security. These materials may also be used in a topical decontaminating cream, in protective coatings, including heavy-metal free anti-fouling coatings, for water purification systems, and a host of other commercial and DoD disinfectant applications.

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KEYWORDS: biocidal polymer, biocide, biological weapon decontamination, biocidal textile

ARMY03-T13 TITLE: Biofilm Remediation for Restoration of Contaminated Army Sites.

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective of this STTR is to develop and exploit technology for restoration of contaminated Army sites, using stable, mixed-species biofilms in a rapid, cost-efficient process for elimination of hazardous energetic and chlorinated organic compounds.

DESCRIPTION: The accumulation of hazardous chemicals in the Army training environment has proceeded for many decades. Restoration is a high priority – but very costly – process, using existing technology. Energetic compounds, such as TNT (trinitrotoluene), RDX (hexahydro-trinitro-triazine), HMX (octahydro-tetranitro-tetrazocine), and chlorinated organic compounds, such as trichloroethylene (TCE), perchloroethylene (PCE), vinyl chloride, and polychlorinated biphenyls (PCBs), are among the most recalcitrant to elimination. Microbial degradation is the most effective and least expensive alternative. Commercial proprietary systems can function in field situations to remediate some chlorinated organic compounds, but they often fail, nor have they been used on explosive materials found at Army sites. This STTR solicits the utilization of basic information and technology that would take advantage of the many beneficial properties of biofilms. This is a unique approach, not known to be duplicated elsewhere, that offers exceptional versatility and flexibility in the organisms that are used and the contaminants to be eliminated. In current microbial approaches, one type of microorganism will initiate the degradation to an intermediate derivative and other species eliminate the accumulated intermediates. However, the growth requirements for the separate organisms can be quite different, severely limiting the utility of the combined activities. This is difficult to stabilize in the usual suspension cultures employed. Thus, current procedures do not reflect the predominant microbial association in natural environments. Consortia of multiple species of organisms associated with surfaces form native biofilms with remarkable stability, unique structural features, and versatile degradative activities. Studies in this relatively new area of microbiology reveal that synergism between combinations of organisms in the films accomplish complex nutritional interactions and environmental modifications that far exceed the sum of the activities of the individual species in pure planktonic (free-swimming) cultures. Stably anchored microcommunities in biofilms have extraordinary adaptive abilities to adverse chemical and physical stresses. Their overall growth rates, survivals, and preference for multiple substrates make biofilms ideal candidates for the complex interspecies interactions required for the degradation of environmental contaminants. Recent work in extractive membrane biofilms and in new culturing regimens for organisms with unique degradative capacities, such as the mycobacteria, previously assumed to be fastidious in their growth, could have enormous impact in biofilm technology.

Mixtures of bacteria and fungi are found growing on microbial platforms for bioremediation, yet this has been relatively unexploited for their complex and unique roles in the degradations of target recalcitrant compounds. The STTR would take advantage of microbial consortia to establish optimal combinations of bacteria and fungi for destruction of the energetic and halogenated compounds. Heretofore, most studies of bioremediation have used monospecies bacterial cultures. Yet, the extraordinary degradative capacity of fungi for intricately complex organic structures is a hallmark of many fungi and saprophytic mycobacteria. The multi-species biofilms proposed for this technological development would take advantage of the cumulative strengths of the microbial flora found in many natural settings. Practical, efficient, and relatively inexpensive field systems for the remediation of Army-relevant recalcitrant hazardous contaminants should be developed.

The technology to be exploited under this STTR would have numerous advantages over current procedures. First, the process is totally natural, using indigenous organisms. Although the biofilms are stable, some organisms could escape the remediation platform. However, they would be natural for that environment. Second, genetically engineered organisms would not be used, eliminating any concern relevant to such unnatural species. Finally, the systems developed with biofilm technology could be allowed to run at ambient temperatures, minimizing energy requirements that often accompany the use of “laboratory” style organisms.

Phase I: Using soil samples and previously identified organisms as inocula, establish mixed-species substance-degrading biofilms in the presence of selected environmental contaminants. Efficacy in degradation and mineralization would be determined.

Phase II: The species from these incubations would be identified and mixed samples of known composition would be used to determine the participants in establishing the biofilms in the degradation of the hazardous substances. Physical and nutritional conditions requisite to establishing and maintaining the biofilms and the attendant degradative capacities would be established.

Phase III DUAL USE APPLICATIONS: Multi-species large-sized platforms would be evaluated. It is recognized that there is greater efficiency in degradation in the larger operations than is seen in laboratory scale operations. Cost comparisons would be made between newly exploited biofilm technology and conventional remediation processes.

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KEYWORDS: Bioremediation, mixed-species biofilms, energetic compounds, chlorinated compounds, site remediation and restoration.

ARMY03-T14 TITLE: <u>Improved Kit for Chemical Detection</u>

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: Design, construct, and test a small lightweight modular test for capable of identifying a broad range of chemical weapons and toxic industrial chemicals (TICs). The developed system should be inexpensive, resistant to chemical interferents, and be very simple to employ by an untrained end-user.

DESCRIPTION: There are many available products and kits that can be used for chemical agent identification, including M8 and M9 paper as well as M256 kits. While paper detection technology is relatively inexpensive and easy to use, agent detection limits and sensitivity to chemical interferents are less than ideal. Available detection kits, while more sensitive to agents, have increased complexity and remain susceptible to chemical interference.

A new detection product is desired that has the ease of use and relative cost of paper-based detection products. This technology must be immune to significant extremes in pH, which in current systems can be a very problematic interferent. The developed product should be able to detect and identify nerve, blood, and blister agents as well as numerous TICs at levels that represent an immediate danger to life and health (IDLH levels). The sensor product(s) should be capable of detecting contamination in solution, in the air or at surfaces and have a response time should be on the order of minutes.

The developed sensor(s) must be resistance to forms of chemical interference that are likely to be present in a field or emergency response environment. Relevant potential forms of interference include, gasoline, kerosene, diesel fuel, exhaust fumes, cleaning solutions, colognes, perfumes, insect repellant, and sunscreen. Sensors must neither exhibit a false positive upon exposure to potential sources of interference nor should they give a false negative in the presence of a target chemical hazard.

PHASE I: Demonstrate ability to detect target chemical hazards at relevant (IDLH) concentrations, resistance to interference, and simplicity of use. Design a prototype modular kit for chemical hazard identification based upon Phase 1 findings.

PHASE II: Construct kits and demonstrate utility for hazard identification. Conduct testing to demonstrate real-world utility and provide a cost analysis suitable for prototype manufacturing of 50 – 200 units to be used in evaluation tests. Contrast system performance against that of conventional chemical detection technology.

PHASE III DUAL-USE APPLICATIONS: A simple to use, inexpensive kit for chemical hazard identification has numerous applications in the military and domestic preparedness community. An efficient kit design would enable the unit to be employed by any emergency first responder including fire, Haz-Mat, and police units.

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KEYWORDS: chemical warfare agents, toxic industrial chemicals, detection kits, sensors

ARMY03-T15 TITLE: <u>Mitochondrial Functional Proteomics</u>

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: To develop a comprehensive platform for mitochondrial proteomics.

DESCRIPTION: Mitochondria generate the energy that fuels the cell. Mitochondrial DNA is not protected by histones, is exposed to high levels of free radicals, and has less DNA repair systems than nuclear DNA. Mutations in mitochondrial DNA and reduction in mitochondrial copy number lead to reduction in cellular energetic capacity. A demonstration of the effect of mitochondrial impairment on human energetics is demonstrated by a clear correlation

between damaged mitochondria, reduced oxidative phosphorylation potential, and age in humans. It is clear that human physical performance capabilities decline with age. This is why boot camp is not populated with 70 year olds. Understanding the mechanisms of mitochondrial DNA damage and repair should lead to a variety of methods to protect mitochondrial DNA and to reduce mitochondrial impairment as people age. In addition, inducing mitochondrial biogenesis should improve and optimize the physical capabilities of military personnel. A military force that protected the mitochondrial DNA of its warfighters would be able to have personnel that functioned at their peak physical abilities longer, reducing personnel turnover and training costs of new recruits, and increasing the amount of experience that personnel at all levels have. In addition, military personnel that were not functioning at the human optimum due to less than optimal mitochondrial levels would be able to improve their physical performance by stimulating mitochondrial biogenesis.
At present all significant forms of mitochondrial DNA repair are encoded by genes that give rise to both nuclear and mitochondrially targeted proteins. In addition, of the estimated 1000 human mitochondrial proteins, only 13 are encoded by the mitochondrial genome. These conditions make mitochondrial genes refractory to identification by classical genetic or microarray approaches. A comprehensive functional proteomics approach is necessary to identify all of the proteins that contribute to mitochondrial stability, biogenesis, and function.

PHASE I: The investigators will set up a functional proteomics system, demonstrating the ability to comprehensively identify all of the mitochondrial proteins. The investigators will demonstrate the ability to identify low abundance proteins, basic proteins, cysteine-containing proteins, and high molecular weight proteins.

PHASE II: The investigators will deliver the finished product – a free publicly accessible database, containing an annotated list of all mitochondrial proteins.

PHASE III: The product developed in phase II – i.e. the mitochondrial database - will spawn a large variety of commercial products in phase III, including drugs and food products to stimulate mitochondrial biogenesis for enhanced mental and physical performance, compounds to stimulate mitochondria to alleviate the symptoms of disease with mitochondrial components (including diabetes, Alzheimers, Parkinsons, MELAS, obesity, cataracts, deafness, and heart disease), food products or compounds to stimulate performance in athletes and warfighters, tests to diagnose mitochondrial defects and deficiencies, and food products or compounds to improve mental and physical capacity in aging humans. Because the database will be publicly accessible, commercial products will be produced by a number of companies, not just the company that developed the database.

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KEYWORDS: mitochondria, proteomics

ARMY03-T16 TITLE: Instrumental Probes for Properties of Nano-structures in Polymer Matrices.

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop non-destructive methods to probe nano-structures in bulk matrices (not on or near the surface). Probe will provide information on properties of adhesion between structures and the matrix. Other properties of interest include nano-structure size, 3-D distribution of nano-structures within the material, nano-structure. Provide measures of signal/noise for range of test materials. Methods providing information on the bulk material are not acceptable; probe must interrogate individual nano-structures.

DESCRIPTION: Nano-structures are objects having dimensions of order 10 –7 to 10-9 meters. Incorporation of nano-structures promises to provide new materials with increased opportunities to tailor to functional requirements. Nano-scale materials have become available during the past decade. Experiments have shown that, in a bulk matrix, nano-structures significantly alter and improve properties of the host (beyond incremental improvements). Examples include toughening of polymer composites by nano-scale metal oxide particles as shown at the US Natick Soldier Center. Electrical properties of plastics have been enormously altered by dispersal of small amounts of fullerene tubes at Cambridge University. These promising beginnings suggest new polymer composites that control permeation, can be made stealthy, etc. New instruments to image and analyze nano-structures structures beneath the surface will enable faster pace of development of this technology.

Study of this problem may focus on two model systems: polymer composites and opto-electronics. Both represent very large classes of materials of great interest to the DOD. The US military uses polymer composites for vehicle and individual protection. Micro-electronic chips and miniature lasers have demonstrated greater capabilities for processing, storing and transporting information. These devices rely upon precise definition of multi-layer materials at the sub-micron scale. The electronic and optical properties of these layers must be controlled and characterized for proper device performance. The probing of these properties becomes even more critical as the device features continue to shrink to nano-scale dimensions. Future devices (e.g., single electron transistors, resonant tunneling devices, quantum dot LEDs and lasers) impose requirements that greatly exceed current capabilities. New techniques and instrumentation equipment must be developed to probe beneath surfaces and interfaces to the regions beneath the surface.

Types of information sought: How can we go beyond atom identification to information about chemistry? Classic chemistry analysis tools that can probe beneath the surface include magnetic resonance and infrared spectroscopy. Magnetic resonance may not be feasible because of low signal to noise. Lasers can be highly focused and spectroscopies (e.g., coherent anti-Stokes Raman) may be feasible probes; but they require transparency in the corresponding part of the spectrum. X-rays and neutrons have long been used to probe at depth: is current practice adequate for information on nano-structures? Electron microscopy is highly developed to provide structure information: can adaptations provide information about chemistry?

Possible approaches include scanning tunneling microscopy and descendent methods – the most dramatic surface characterization tools of the last decade. Can they be adapted to probe beneath the surface (e.g., Ballistic Electron Emission Spectroscopy)? Similarly, photoelectron and Auger electron spectroscopy revolutionized surface science in the 1970s: can they or some variant on them be adapted? Various nuclear methods (e.g., proton, and alpha back-scatter) are used for material profiles. Does straggling rule out their use to characterize structures on the nanometer scale?

PHASE I: Develop or acquire suitable test materials for testing optical spectroscopic, magnetic resonance or other probes of nano-structures in bulk matrices. Develop rationale for most promising probe technique and perform initial experimental studies. Report efficacy of probes for determining sizes and spatial distribution of nano-structures.

PHASE II: Based on convincing rationale for choice of probe, determine properties of interfaces between nano-structures and host matrices. These properties include differences between surface properties of the nano-structure in and outside the host matrix, measures of adhesion as predictors of material mechanical properties,

PHASE III DUAL USE APPLICATIONS: Effective probes for nano-structures in bulk composites will revolutionize our understanding of complex materials and accelerate the development of new materials with complex functions.

KEYWORDS: composite material, nano-structures, opto-electronic

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2. www.nano.gov

KEYWORDS: composite material, nano-structures, opto-electronic

ARMY03-T17 TITLE: Early Detection of Neurotoxic Effects with a Wearable Monitor

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: Using non-invasive brain wave, eye movement, pupillary dynamics and/or other bioelectric/physiological response recording coupled to innovative analysis systems (e.g. complexity/chaos analysis), create a lightweight, wearable device capable of real-time alarms to detect impending cognitive dysfunction upon e.g. occult exposure to chemical and/or biological agents, significant sleep loss, excessive uncompensated stress levels, etc., before significant disability occurs.

DESCRIPTION: Advances in the understanding of normal healthy variability in physiological systems opens the possibility that early detection of loss in the freedom to vary, i.e. a reduction in complexity in a system may act as a very sensitive measure of system compromise. The human nervous system, as not only the intended target of neurotoxic agents, but also one of the most sensitive of detectors, may respond in a measurable fashion before significant changes in the cognitive state of the individual occur. Such sub-clinical changes may provide sufficient forewarning of protective posture failure that tactical effectiveness could be maintained. Further, similar changes can be noted in physiological indices with stressors such as sleep deprivation and/or information over/underload. Since the eyes contain an exposed section of the brain, i.e. the retina, as well as reactive tissue under sympathetic/parasympathetic control (the pupil), monitoring of visual cortex and/or pupillary and ocular-motor dynamics as well as other measures (e.g. galvanic skin response, electrocardiograms) might provide the data needed for such a real-time early warning system. Creative application of the interface between physiology and computer-based sensors may permit this device to extend its use into monitoring generalized physiological status and stress levels as well as the specific uses indicated above.

PHASE I: Develop overall system design that includes specification of functions to be monitored, sensor implementation, analysis protocols and operation. Demonstrate functioning “brass-board” components in a non-human biological model system.

PHASE II: Develop and demonstrate a freestanding (portable) proof-of-concept system for human use in a normal civilian environment. Conduct testing to prove feasibility over extended operating conditions.

PHASE III DUAL USE APPLICATIONS: This system could be used in a broad range of military and civilian medical and psychological applications where automatic surveillance of cognitive state would be useful – for example, in airport traffic controllers, or security monitors for industrial facilities.

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KEYWORDS: Physiology, Analysis, Cognition, Real-time, Wearable Computers, Biological Sensors

ARMY03-T18 TITLE: Remote Detection of Riverine Traffic

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: PM RSTA

OBJECTIVE: Develop innovative stand-alone, sensor suites to detect, characterize, and track powered and non-powered surface craft. The sensor suite must be combined with a communications system that permits transmission to a command center in near real time through adverse environmental conditions, such as triple canopy tropical foliage.

DESCRIPTION: A research and development effort is requested to establish and validate a suite of sensors and their characterizing algorithms to detect, analyze, track and report position, speed, and direction of travel of watercraft in interior waterways. Imaging and/or non-imaging sensors may be used for characterization and identification. Possible sensor technologies may include, but are not limited to: acoustic/sonar, seismic, magnetic, active or passive infrared technologies, or radar. Multi-sensor data fusion may be used to produce synergies among the selected sensors. An obvious example is the use of “trip-wire” sensors to trigger other more descriptive sensors. Such a combination will serve to mitigate power requirements. Several of the sensors respond to different physical phenomena, and this sensor independence may be used to mitigate false detections as well as provide operation over a broader range of conditions than are possible with a single sensor. The sensor suite should be self-organizing and provide continued operation in the event that an individual detector becomes inoperable. Placement of sensors is discretionary and may be in the water or on nearby landmass or both, however, sensors should be inconspicuous and able to be easily deployed by hand, aircraft, or watercraft. Sensors should have a mission life of no less than 180 days and be renewable. Sensors/algorithms and communications should be transferable to allied foreign entities for emplacement and monitoring. The performance of the sensor system should exceed that of the Improved Remotely Monitored Battlefield Sensor System (IREMBASS) and be able to detect and track canoes and rowboats, as well as, sail or gasoline-powered craft in rivers 100 - 500 meters wide.

PHASE I: Demonstrate a prototype sensor mix and algorithms to detect on-the-move watercraft, including direction of travel and speed. Determine expected probability of detection versus false alarms for an optimized system based on reasonable assumptions. Identify path for improvements to meet conditions of deployability, self-configuration, and life span as indicated above. Also, identify a communication system – sensor combination that permits transmission to a command center in near real time under adverse environmental conditions.

PHASE II: Assemble and test an optimized sensor suite and communication system that is inconspicuous and meets conditions of self-configuration, communication, and life span; and can be deployed and renewed as indicated above. System should have high probability of detection of surface craft with low false alarms, as well as tracking capability. Identify different system configurations for different scenarios, if necessary. At end of Phase II, system should be available for testing by DOD personnel, who may assess and analyze the effectiveness of single, and multi-target surface craft acquisition and characterization in clear and inclement weather, and the system's ability to disregard false alarms

PHASE III DUAL-USE APPLICATIONS: Phase III work would involve development of ruggedized and robust sensors for actual deployment. Different sensor suites may be developed to allow for changing scenarios. Intelligence and homeland defense applications could directly benefit from having a standoff detection device for river craft. Applications include surveillance for counterdrug activities as well as terrorist movements along rivers in both the US and allied nations. Additionally, US and other country departments of the interior may consider the system's use to monitor fishing and other river traffic.

OPERATING AND SUPPORT (O&S) COST REDUCTION (OSCR): Optimized sensors will be more reliable, have a faster response time, and provide a substantial force multiplication factor by using machines instead of humans to monitor water borne activities

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KEYWORDS: river surveillance, algorithms, networked sensors

ARMY03-T19 TITLE: Narrow-Band Infrared Obscurants for Survivability

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Define a Narrow-Band Infrared (IR) spectral Obscurant Material and a manufacturing process that is capable of producing the material at a price goal of $10 per pound.

DESCRIPTION: The current infrared screening materials block the total visual and infrared spectra to approximately the same extent. There is interest in developing an obscurant material that will block only the infrared region or specific portions of the infrared region. Narrow band obscuration has been demonstrated in the millimeter region of the electromagnetic spectrum and this ability must now be expanded to include the infrared region. This will allow selective screening using obscurants.

Narrow-band has several levels of useful definition. The 1st level would be an obscurant that blocked only the infrared region (0.7-12.0 micron wavelength). The 2nd level would be an obscurant for the near-infrared (0.7-2.0 micron wavelength), mid-infrared (3.0-5.0 micron wavelength) or the far-infrared (8.0-12.0 micron wavelength). The 3rd level would be an obscurant that would block a specific wavelenght such as the 1.06, 1.54 or 10.6 micron wavelength. Depending on the specific region chosen the physical basis for narrow-band IR extinction could be control of the physical screening particle size parameters or individual molecule interaction mechanisms.

PHASE I: Identify obscurant materials having characteristics that will block only the infrared region or specific portions of the infrared region. Recommend one or more materials which laboratory experimentation demonstrates to have the greatest potential as a narrow band IR obscurant. Consideration should be given to the cost goal and feasibility to manufacture in commercial quantities.

PHASE II: Develop samples of the material or materials selected in Phase I, and produce sufficient quantities (1 - 10 kilograms) for chamber evaluation. Conduct frequency dependent obscurant characterization to demonstrate that the

Phase II results meet the research objective. Provide a 5 kilogram sample for Army evaluation at no cost to the contractor. Show that it is feasible to commercially produce the material economically and in kilogram quantities.

PHASE III DUAL USE APPLICATIONS: This material has potential commercial use in hostage recovery situations and break-in protection/security systems, paint pigments, makeup, Electromagnetic Interference (EMI) shielding, batteries. The military application is in IR threat sensor countermeasures.

REFERENCES:
"Smoke Units Viable to IBCT and Objective Force", Army Chemical Review, Aug 2001; Superintendent of Documents, PO Box 371954, Pittsburgh, PA 15250-7954.

KEYWORDS: smoke, obscurant, screening material, infrared

ARMY03-T20 TITLE: Enhanced Vapor, Aerosol, and Particulate Sampling System for Optical Trigger Technologies

TECHNOLOGY AREAS: Chemical/Bio Defense

Objective: Develop an improved vapor, aerosol, and particulate sampling system for optical trigger technologies for chemical and biological sensor systems.

Description: An optical trigger technology is an air-monitoring sampling system that operates continuously and exploits the spectral properties of a hazardous air pollutant in order to effect a warning signal. The most basic type of optical trigger is an aerodynamic particle sizer, which draws a sample of air through an interrogation chamber where a light beam or laser interacts with particles to produce optical scattering. A detector measures the scattering statistically to provide information on the particle density and size distribution. In controlled environments, a sudden change in aerosol size distribution could correlate to a hazardous event such as a biological agent release. More recently, efforts have been made to add fluorescence capability to an aerodynamic particle sizer to further characterize the particulates. Optical triggers can improve the performance and reduce the operating costs of a chemical or biological detection system by conserving reagents and consumables until a hazardous event is detected. In ambient outdoor environments, however, particulate, liquid aerosol, and vapor constituents can change dramatically over a very short time frame, producing a highly cluttered background that frustrates the performance of optical triggers. There is significant margin for innovation in air sampling technology with an aim to reduce the impact of clutter by (1) adsorbing dilute vapors onto a solid medium or substrate, (2) sorting particulate matter into size bins based on, e.g., mechanical, electrostatic, or aerodynamic properties and (3) concentrating individual particle size populations either in flight or on a medium such as an impactor or a filter medium. In order for the technology to be compatible with optical trigger operation, the substrate or filter medium should not present an excessive absorption cross-section vis-à-vis the target analyte materials of interest or concern.

Phase I: Under the Phase I effort, a comprehensive study will be performed to describe and/or model a device capable of collection, separation, and preconcentration of organic vapors, solid particulates, and liquid aerosol droplets as a function of particle size. The preferred technology will function with minimum consumable (reagents, materials, and power) requirements. Particle size sorting has been demonstrated in the literature, and commercial devices such as virtual and cascade impactors are currently used to collect and study airborne particulates. To be compatible with an optical trigger application, the airborne material must be collected or adsorbed onto a medium that affords little or no absorption of electromagnetic radiation, particularly in the ultraviolet/visible region. Materials that afford “windows” in other electromagnetic spectral regions, particularly near, mid, and long wave infrared, are also considered to be viable solutions. An example of a suitable substrate that spans most of the electromagnetic spectrum would be a smooth or roughened metallic surface that presents a reflective background. Alternatively, methods that generate a stream of particles binned by particle size in a flow-through setting chamber are also of interest. A multi-stage device may collect various ranges of particles onto separate stages that would be interrogated by an optical spectrometer coupled to the stage using transfer optics or optical fibers. The final stage of the device may consist of a sorbent material that affords the additional capability to collect organic vapors for optical analysis. A preferred approach would incorporate a means of periodically renewing the surface in each stage, either purging the collected material or trapping it onto a separate substrate for archival purposes or further laboratory analysis.

Phase II: Under Phase II of the effort, a prototype sampling system would be constructed and tested, and the design would be refined to optimize performance. The independent stages can be periodically removed in the initial prototype/demonstration platform (year 1 of the Phase II effort) for measurement offline in a commercial benchtop spectrometer. In the second year of the Phase II effort, a prototype that incorporates a field spectrometer system optically coupled to the collector for online analysis will be constructed and tested. An effort should be presented that leverages commercial, off-the-shelf (COTS) technologies for the field spectrometer, and an objective of the effort should be to keep the overall system costs low. Throughout the Phase II effort, methods and materials that allow for rapid substrate clear down and/or renewal will be explored to optimize the system performance in an autonomous operational test. Algorithms for the spectrometer system would be developed that correlate the collected materials against known optical properties of target analytes, and also control the sampling system so that surface renewal or sample harvesting/archiving may be implemented on demand whenever either of the following circumstances is detected: (1) the baseline becomes distorted or a highly absorbing matrix accumulates that defeats the dynamic range of the spectrometer system, or (2) an analyte of possible concern is detected. In the military application, the target analytes would include but may not be limited to volatile and nonvolatile toxic organic chemicals (e.g., chemical warfare agents) and pathogenic bacteria, viruses, rickettsiae, and toxins.

Phase III Dual Use Applications: This technology would have a viable market as a continuous air quality monitor for industrial and environmental hygiene applications, manufacturing process monitoring and control, medical and manufacturing air monitoring, counterterrorism/homeland defense applications, and military contamination avoidance. An integrated, modular chemical-biological agent detection system is identified as a priority technology need in the Joint Services Contamination Avoidance business area.

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KEYWORDS: optical, sensor, aerosol, collector, chemical detection, biological detection, particle sampler, process control, spectrometer, air monitor, industrial, environmental hygiene

ARMY03-T21 TITLE: <u>Obscurant Dissemination</u>

TECHNOLOGY AREAS: Materials/Processes

Objective: Develop a means to aerosolize high-aspect ratio solid particles with minor dimensions below one micron.

Description: Obscurants are used as countermeasures to sensors. For infrared and radar applications efficient obscurant particles are, by necessity, high-aspect ratio, electrically-conductive fibers or flakes with small minor dimensions (nanoparticles are interesting candidates). To be militarily useful these materials must be efficiently aerosolized. To be tactically useful, the energy source for dissemination must be self-contained and portable and, hopefully, small in relation to obscurant payload. Traditional dissemination mechanisms are explosives, pyrotechnics and pneumatics.

To be logistically feasible, obscurant materials will have to be densely packed. Small, high-aspect ratio particles will be held together by van der Waal's forces, making aerosolization problematic. Innovative packing techniques may include coatings or surface modification or preferential orientation of particles. They may require the addition of a separating medium, either solid or liquid, although this will reduce the percentage of active obscurant being delivered. All concepts will require tradeoffs of packing density, deagglomeration efficiency and the ratio of obscurant to carrier. The dissemination mechanisms (including but not limited to explosive, pyrotechnic and pneumatic) will have unique advantages that will aid dissemination and limitations that will hinder it.

PHASE I: Identify difficult to disseminate obscurant materials having characteristics such as highly conductive (most likely metal) nanoparticle fibers and flakes. Recommend one or more dissemination methods which laboratory experimentation demonstrates to have the greatest potential. Consideration should be given to a payload efficient method within volume constraints and feasibility to produce in commercial quantities.

PHASE II: Develop dissemination prototypes for obscurant materials selected in Phase I, and produce sufficient quantities for chamber evaluation. Conduct aerosol characterization to demonstrate that the Phase II results meet the research objective. Provide 5 prototypes for Army evaluation at no cost to the contractor. Show that it is feasible to commercially produce the devices.

PHASE III DUAL USE APPLICATIONS: Examples of Dual-Use Applications: The primary military use of this technology would be to develop munitions for obscuration. This technology would have commercial application in the areas of paints and coatings and in composites for electromagnetic shielding.

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KEYWORDS: smoke, obscurant, screening material, infrared, aerosols, nanoparticles

ARMY03-T22 TITLE: Metabolic Bio-inspired Batteries

TECHNOLOGY AREAS: Materials/Processes

Objective: The objective of this topic is to design bio-inspired batteries based on basic principles of bioenergetics and metabolic engineering for a wide variety of applications. Such batteries would emulate cellular production of adenosine triphosphate (ATP), the biological currency of energy, and produce usable electricity with water as a by-product by combining the biochemistry of ATP with the engineering of a fuel cell.

Description: A large percentage of the weight carried by soldiers is in batteries, and reducing this logistical burden and providing alternate, in theatre, energy sources are high priorities. A biological approach would be based on applying new understanding of the metabolic processes in cellular energy production and duplicating them in biochemically based stand-alone batteries. ATP is the “currency” of bioenergetics and is produced by all living things. The biochemical and biomechanical processes involved have been intensively studied and most key features are well understood. Interestingly, features of the system include tiny molecular machines which spin at several thousand rpm during ATP synthesis. These macromolecular proteins known as supercomplexes or respirasomes can be manipulated genetically in many experimental models, including yeast. The focus would be to duplicate this energy producing process with resulting energy flow and benign by-products of respiration, i.e., CO2 and H2O. Subsequent testing would explore additional means to amplify, control, research temperature boundaries and sensitivities, along with mechanisms to produce spike as well as uniform voltages. Metabolic bio-inspired batteries could be constructed by replicating in a laboratory device the electrical potential created during cellular matabolism. Candidate prototypes would use biochemical components in small milliliter volumes under ambient room conditions to enable an electrical circuit. Preliminary experiments using a very simple ATP variant composition have demonstrated measurable and reproducible results in the laboratory setting. If the fundamental application of metabolic processes to battery production is broadly successful, there could be large-scale replacement of logistically burdensome, environmentally hazardous, chemical and metal batteries by re-usable, disposable, environmentally safe biochemical batteries. Further, bio-inspired batteries would support forward and on-board manufacturing of electrical power sources for the Objective Force concept.

Phase I: Phase I will select a metabolic model and describe a proof of concept design to produce usable energy from a biological source. Initial experiments will demonstrate energy production and describe the initial condition and design for a “biological battery.”

Phase II: Phase II will focus on identifying and prototyping the most likely bio-battery powered applications for the Objective Force concept. Specifically, the research would move toward the development of prototype applications that meet what we believe are the highest priority Objective Force needs that fit this profile. These include, but are not limited to:

- Stand-alone sensor power
- Power for implantable sensors
- Soldier power to support the individual sensor suite (multiple, integrated sensors)
- Biodegradable battery for remote field use
- Ambient use of human body as power source for small voltages (creating the same power generation model by tapping into ambient metabolic processes)
- Forward manufacturing technologies to produce battery constituents

Phase III Dual Use Applications: Bio-inspired batteries could provide a simple, efficient, alternative to current technologies and materials. Further, these power sources would be re-usable, environmentally safe and the constituents needed to produce the biochemical production of energy could be manufactured well forward in the battle space. The development of biochemical batteries that benefit unique military applications would provide the initial commercial market for application. Once adequate prototypes from the research laboratory are assured, venture capital, possibly from the proposed Army venture capital fund for soldier power, would be pursued to establish a production facility. Broader civilian applications would be pursued concurrently, focused on the medical market, the environmentally sensitive user market and ultimately mainstream device power applications.

Potential commercial applications: In-vivo power generation for life support devices; power generation for small-scale, low voltage unattended medical and security sensors; power generation for hand-held electrical devices; alternative auxiliary power generation for field generators and field power supplies.

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KEYWORDS: Soldier Power, Energy, Biotechnology, Biosensors, Sensors, Fuel Cells

ARMY03-T23 TITLE: Optical Communication Techniques for Improving Standoff Detection of Chemical and Biological Agents

TECHNOLOGY AREAS: Chemical/Bio Defense

Objective: To apply techniques developed for optical communication towards improving detection sensitivity of optically-based standoff chemical and biological (CB) sensors.

Description: Standoff passive and active (Light Detection and Ranging: LIDAR) systems are currently being developed by the Department of Defense (DoD) to answer the chemical and biological threat. Systems such as the Artemis, Warning and Identification LIDAR Detector for Countering Agent Threats (WILDCAT)1, Joint Service Lightweight Standoff Chemical agent Detector (JSLSCD), Joint Biological Standoff Detection System (JBSDS) are currently the state of the art in standoff chemical and biological detection systems. These techniques use ultraviolet (200-400nm), mid-wave (3-5microns) and long-wave (7-12micron) infrared to detect and identify agent releases.

In order to boost the signal to noise ratio, transmitter power and receiver sensitivity are pushed to the material limits. Electronic amplification of the signal is usually applied after A/D conversion of the optical signal thus adding to the noise. If optical amplification techniques can be applied, theoretically the signal strength can be increased with minimal noise amplification.

Another communication technique that may benefit Standoff Detection are wavelength division multiplexing (WDM) and demultiplexing for the purpose of simultaneous, multiple wavelength emission and detection. In many applications, several wavelengths are used to identify the spectral identity of an agent. These wavelengths are usually emitted sequentially. Depending on the number of wavelengths emitted and the repetition rate of the laser, the sensor system may not be fast enough to gather meaningful information on an event, which may also be in motion.

The last two paragraphs depict instances where, with the right materials, optical communication techniques may be applied to standoff detection problems. They are by no means the only techniques of interest for bio-chemical detection.

There is a considerable amount of technical risk involved in applying optical amplification and WDM to standoff CB detection. Significant flexibility in formulating approaches will be allowed, and innovative solutions are sought.

Phase I: Demonstrate the feasibility of optical communication materials and/or techniques to be applied to one or more of the wavelength regions of interest. Final demonstration should be through a combination of theoretical modeling and controlled laboratory demonstration to support the model.

Phase II: Create devices that may be tested against conventional techniques to show improvement in detection sensitivity. The devices may be breadboard in nature and optical input or output does not necessarily have to match current, military sensor technology, though this would be preferable.

Phase III Dual Use Applications: Phase III military applications will include packaged devices that may be easily retrofitted to current sensor packages. This may include improvements in the acceptable input power (lower or higher, depending on the type and purpose of the device). Phase III commercial applications include spin-off devices for improving standoff sensors for environmental pollution monitoring and for biological contamination monitoring in food service industries.

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David Cohn, Eric Griffin, Louis Klaras, Cynthia Swim, Anna Wong, “WILDCAT Chemical Sensor,” Proc. of the Fifth Joint Conference on Standoff Detection for Chemical and Biological Defense, 2001.

KEYWORDS: optical communication, optical amplification, wavelength division multiplexing, wavelength demultiplexing, Light Detection and Ranging: LIDAR, Standoff Detection of Chemical and Biological Agents.

ARMY03-T24 TITLE: Nanocapsules for Biological Warfare Agent Detection and Neutralization for Immune Buildings

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: The objective of this research is to develop and test smart coatings or appliqués containing nanocapsules that have the potential for application in biological warfare agent detection and neutralization for immune buildings.

DESCRIPTION: Recent laboratory experiments have shown that smart coatings, that are also self-healing, can be produced by incorporating microcapsules that contain coating healing compounds and corrosion inhibitors. This effort would use similar principles to develop nanocapsules that can used to detect and neutralize biological warfare agents, such as anthrax. The nanocapsules would be incorporated into appliqués to produce smart coatings that can signal the presence of a specific biological warfare agent, for example by causing a color change. The nanocapsules would also release compounds, such as chlorine dioxide, that could neutralize the biological warfare agent. The triggering mechanisms for these reactions could be spore growth or the presence of specific amino acids contained by the biological warfare agent.

PHASE I: Determine the feasibility of incorporating nanaocapsules in smart coatings or appliqués that can be used in buildings to detect and neutralize biological warfare agent release.

PHASE II: Develop smart coatings or appliqués containing nanaocapsules to detect and neutralize biological warfare agents, such as anthrax, that can be applied to buildings to enhance their immunity to internal or external biological warfare agent release.

PHASE III DUAL USE APPLICATIONS: Military and civilian buildings, such as command/control centers, will be far less attractive targets for attacks by airborne/aerosolized biological warfare agents, when augmented with the capability for the detection and neutralization of biological warfare agents. The application of detection and neutralizing chemicals to building infrastructure will greatly reduce the effectiveness of any such attack.

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KEYWORDS: Coatings, Biological Warfare Agent, Immune Building, Internal Release, Appliqué

ARMY03-T25 TITLE: Electrospray Fluorescence Dosimeter for Biological and Chemical Detection

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The objective of this STTR is to design and build a small, portable electrospray dosimeter that can be worn by soldiers as a way to record their exposure to chemical and biological agents. In later phase developments, the unit will be integrated with global positioning that will issue a time-stamp for critical exposure data.

DESCRIPTION: There is a need for near-real time detection and location of airborne biological and chemical agents in small (ppb and ppt) quantities by the warfighter. Although the concentration of chemical or biological material may not be sufficient in a peripheral encounter to cause contamination, levels may be high enough for detection and warning providing a first alert for a release. The technology sought by this proposal is based upon experiments using charged droplets, produced by electrospray dispersion of a conducting liquid (solvent) into gas as a fine spray of tiny droplets. As the solvent evaporates, polar solute species are transformed into free gas phase ions. The charged droplets produced by electrospraying liquids effectively harvest particles and neutral polar molecules in the air. When such a particle or molecule collides with a charged droplet, it attaches to that droplet. If the attaching species is a polar molecule, it subsequently becomes a gas-phase molecular ion, just as if it had been a solute in the original (electrosprayed) liquid. Both particles and polar molecules can be driven to a desired target surface by a directed electric field. It is envisioned that a small (cigarette pack - size or less) sampler could be developed that would disperse a fluorescing solvent under battery power to a suitable target (conductor) surface. The target strip would then be quickly assayed or interrogated using traditional methods of spectrofluormetry, mass spectrometry, chromatography, etc… Integration of global positioning with the dosimeter will permit the re-construction of location and encounter by a warfighter that has passed into a chemical or biological airborne release.

PHASE I: Design, develop and assemble the dosimeter hardware including power supply, solvent dispersion mechanism, and suitable target surface into a working prototype. Test fluorogenic solvent preparations required for the detection of Saren and Bacillus agents.

PHASE II: Demonstrate prototype system from Phase I effort. Test under a range of controlled dispersals of surrogate agents. Apply different analytical chemistry procedures for elucidating "harvested" ionized chemical components. Integrate global positioning with the unit for mapping and location of detected agents.

PHASE III DUAL USE APPLICATIONS: Such a device has broad dual use applications from monitoring environmental air quality for human breathing ailments to expanded military uses including non-man portable vehicular monitors. Additionally, dosimetry can be adapted to monitor plant volatiles that are indicative of subtle changes on the environment due to contamination.

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KEYWORDS: electrospray ionization, dosimeter, fluorescence, charged droplets

ARMY03-T26 TITLE: <u>Optimized Fluorescent Transgenic Bioreporters</u>

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: The objective of this STTR is to apply genetic engineering to develop suitable vascular plant phenotypes and genotypes that are optimized bioreporters for the specific detection of TNT munitions contaminants. These bioreporters will signal the detection of TNT-based munitions contaminants using inducible expression of fluorescent proteins. Furthermore the plants will possess morphological characteristics (e.g., large leaf surfaces, reduced pubescence) that make them efficient targets for remote sensing.

DESCRIPTION: Plants have been used as indicators of environmental insult and contamination for many years. Up until recently, only passive reflectance-based approaches characterizing plant stress were useful in helping to synoptically detect many contaminants. Recent research in phytoremediation has been successful in demonstrating the applicability of genetic engineering to control not only the transduction of a signal for gene expression, but also the selection of plants with desirable morphological traits beneficial to remote sensing. Work by Chiu et al. (1996) and Meahger (1997) have demonstrated improved specificity for signal induction elicited by target compounds. This project will take advantage of that specificity for fluorescence expression stimulated by TNT.
Expression of fluorescent proteins due to induction related to specific contaminants is recoverable by laser-induced fluorescence imaging. However, signal recovery depends upon many things to accomplish confident remote sensing using fluorescence. These attributes include large leaf areas and the location of inducible genes within the plant (i.e., conductive versus aerial tissues). Cultivation of plants having the appropriate fluorophores and morphological attributes would raise the efficiency of plants as bioreporters. These plants would have attributes suited for

bioreporting at synoptic scales since they would be cultivated over areas that could be potentially large in relation to the extent of contaminantion. It is envisioned that a "tool box" approach could be used in the selection of specific cultivars for specific sensing requirements.

PHASE I: Screen desirable morphological traits that may exist in Arabidopsis thaliana (or other suitable candidate with a mapped genome) that may be cultivated to produce optimized bioreporters. Use fluorescence expression (triggered by TNT) to demonstrate signal recovery of fluorescent proteins based on the location of promoter genes in different tissues.

PHASE II: Demonstrate the recovery of fluorescence by laser imaging using green or red fluorescent proteins in other plants such as tobacco (based upon the findings using the Arabidopsis model). Produce a variety of plant phenotypes and genotypes (Arabidopsis or other) having the most desirable attributes for remote sensing TNT contaminants.

PHASE III DUAL USE APPLICATIONS: Optimized fluorescent bioreporters will have a wide range of applications in both military and civil domains. Ideally, plants will be developed for applications ranging from non-proliferation of weapons of mass destruction to remediation and monitoring for military base realignment and closure. Additional uses may involve more operational military components where time is not a critical factor. In this case, plant bioreproters linked to mechanical stimulation and subsequent expression of fluorescence will be examined.

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KEYWORDS: bioreporters, fluorescence, remote sensing, gene expression, genetic engineering

ARMY03-T27 TITLE: Indicator of Base Excess Status

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: To design a device, that can be used by medics in the field under extreme environmental conditions, to measure base excess and indicate whether the value measured is at a severe level.

DESCRIPTION: Recent studies have demonstrated that rebleeding occurs following aggressive resuscitation back to normal blood pressure in the pre-hospital period with experimental subjects that have a vascular injury (1). In response to these findings, the military doctrine for battlefield resuscitation is changing and casualties will only receive sufficient fluid resuscitation to maintain a level of consciousness. Many of the casualties will have low blood pressures and it is possible that some casualties will have progressive shock under these conditions. In ongoing animals studies of low volume resuscitation for prolonged periods of time, elevated base excess is an early marker of progressive shock. This agrees with the clinical literature that indicates that base excess is a good predictor of outcome (2). Measurement of base excess with a field expedient system would allow the medic to recognize those casualties who should be prioritized for early evacuation or alternative resuscitation strategies.

PHASE I: This phase should result in a proof of concept workable device. The base excess monitor should be something that the medic can measure base excess in a drop of blood applied to a paper strip or similar concept (eg, monitor) that will turn color (or show an LCD number) for use in light conditions and fluoresce (or similar capability, eg, LED) for use in dark conditions. The device must be readable in low light conditions but must not emit bright light. A Green-Yellow-Red indicator scheme would be ideal, but a one-color scheme would be acceptable. Green could be for positive base excess. Yellow could be for base excess between zero and –5 mmol/L. Red could be for base excess below –5 mmol/L. If one color, it should be able to detect base excess less than or equal to –5 mmol/L. Other comparable rating schemes would be acceptable.

PHASE II: This phase should result in a device that can be used to identify a severe shock state. The laboratory at the US Army Institute of Surgical Research has experimental models of severe shock that can be used to test the device against invasively derived, standard measurements of base excess. This phase should also result in a durable device that can be used under conditions that will be found in the battlefield. This device should be durable, stable under dusty conditions, stable at temperature extremes, stable at variable moisture conditions, stable at high altitude, able to be carried in combat (ie, crush-proof), have a minimum shelf-life of 2 years, be able to give a reading within one minute (immediately or in seconds would be even better), not require any mixing or preparation, either not require energy or be self-contained with its own power source, be lightweight (1 ounce or less), be inexpensive, and be disposable (or the sampling device be disposable if a monitor is involved).

PHASE III DUAL USE APPLICATIONS: This instrument would have immediate battlefield application and civilian pre-hospital application to be used by paramedics in the field or on ambulances. This may particularly apply to rural or other delayed extraction situations where a reliable monitor for severity of shock state and adequacy of resuscitation may be needed.

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KEYWORDS: Hemorrhagic shock, Resuscitation, Base excess

ARMY03-T28 TITLE: Production of Ready-to-use DNA-based Diagnostics Kit for Dengue Virus Detection

TECHNOLOGY AREAS: Biomedical

Objective: The ultimate goal of the current effort is to transit the mature real-time RT-PCR technolgy of the dengue 3'-noncoding region based assay system (developed by Walter Reed Army Institute of Research) into a field deployable and user-friendly diagnostics device, so that the dengue diagnostics technology can be used in the dengue virus endemic areas where the US military may be deployed in the future. Production of commerically ready dengue diagnostics kit will extend the current dengue virus detection capacity of US Army Medical Command to detect all other viruses belonging to the Flavivirus Family, such as Yellow Fever virus, Japanese Encephalitis, West Nile Virus, St. Louis Encephalitis, etc.

Description: The family Flaviviridae contains almost 70 viruses including those causing yellow fever, dengue fever, West Nile fever and Japanese encephalitis. Recurrent outbreaks of St. Louis encephalitis virus and a recent outbreak of West Nile virus started in New York City and expanded to the whole eastern coast of US illustrated an additional dimension of Flavivirus infection in areas outside tropical and sub-tropical regions. There are four distinct dengue virus types (dengue 1, 2, 3, and 4) each capable of causing disease in humans. Diagnoses of dengue virus infections

at the serotype level may provide an important medical intelligence for the future US military deployments to dengue endemic areas.
The conserved 3'-noncoding sequences of four dengue virus serotypes have been successfully utilized to develop as a TaqMan-based RT-PCR (funded by MIDRP STO A/L from 2002-2003) to quantitatively identify dengue viruses from different regions of the world. However, the quantitative nature of dengue RT-PCR assay is not a simple task to achieve. Thus, it is desirable to identify appropriate commercial partner to produce consistent quality of dengue RT-PCR reagent as ready-to-use kits that can be used by lab technician with no special training experience.

Phase I: Optimize and scale up production of the fluorogenic RT-PCR reagent kits for generic and serotype-specific dengue virus detection. Special freeze-drying protocol and instrumentation will be developed to generate dried and read-to-use dengue assay kits that can be used in different fluorogenic PCR thermal cyclers.

Phase II: Validate the ready-to-use dengue diagnostics kit under laboratory conditions using culture derived dengue viruses as well as clinically confirmed dengue infected samples of different geographic origins.

Phase III: Conduct large scale field trials in dengue endemic areas to evaluate the detection efficacy of ready-to-use dengue diagnostics kits deployed under non-ideal laboratory conditions, such as southeastern Asia and south America. Shelf life of the dengue diagnostics kits will be investigated under field conditions, i.e., extended storage at room, or even elevated temperature. In addition, the current dengue 3'-noncoding region based RT-PCR technology can also be expanded to the diagnostics of other militarilly relevalent Flaviviruses, such as Japanese Encephalitis virus, Yellow Fever virus, and West Nile virus, etc.

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KEYWORDS: Flavivirus, Dengue virus, Dengue serotype, fluorogenic RT-PCR, quantitative diagnostics, JE, yellow fever, West Nile virus.

ARMY03-T29 TITLE: Penetrating Head Injury Model for Multiple Species and Multiple Threat Levels

TECHNOLOGY AREAS: Biomedical

Objective: Develop a device by which penetrating head injury of any threat level may be reliably and humanely reproduced in experimental animals of all species.

Description: The device must be a mechanical instrument based on sound scientific principles. The device should be constructed such that the physics of the device itself and the biophysics of injury can be modeled in a future simulated environment, leading to reduced reliance on animal use. It must be applicable for use in any subject animal species to include and not limited to mouse, rat, swine and non-human primate. The instrument must reliably reproduce a penetrating injury from either non-ballistic or ballistic etiologies and at any threat level. All salient pathophysiologic aspects of injury must be replicated in the animal model. The device must not use a fired projectile. The device must be minimally invasive and minimize the number of subject animals needed for relevant research. The device must humanely replicate this injury in animals.
Animal rights groups have been successful in their opposition to animal models that employed fired projectiles (8). For this reason, the device must not use a fired projectile. However, the device must replicate all of the relevant biophysical and pathopysiologic elements of a penetrating head injury.
All work must be compliant with DoD's application of the Animal Rights Act and other federal policies regarding use of animals in research.

Traumatic brain injury (TBI) is the leading cause of death and disability among young adults (18-40 years old) in the U.S.(1,2) In the military, it accounts for over 50% of deaths among soldiers who have reached medical care (3). As distinct from its civilian counterpart, military TBI is predominantly due to penetrating injury from gunshot or shrapnel (4,5). Civilian TBI is mostly concussive or closed head injury(1,2). However, in certain civilian sectors such as among poor inner city minorities, penetrating etiologies are more common (6). At present, there is no specific therapy for ameliorating TBI. Current therapeutic approaches are focused on preserving general physiology in order to prevent further injury(7). However, there are no specific neuron saving approaches.
An important reason that advances have not been made towards developing rational effective treatments for penetrating TBI has been the lack of an appropriate animal model. The previous models, though experimentally sound, were abandoned due to political and social pressures (8). Thus, a new model is needed but avoids the drawbacks of previous models such as using a fired projectile. This new model must reproduce all of the important features of penetrating head injury (9-12). Only in this manner can new treatments be developed and tested before initiating human clinical trial. Further, only by using this approach can a meaningful advance be made in treating this important combat casualty.

Phase I: Develop and produce a design of a device. The level of injury produced should be moderate-severe. Specifically, at least 50% of animals should survive the initial injury and have demonstrable neurologic deficits. All relevant neurophysiologic and biophysical effects of penetrating objects need to be reproduced by this model. The successful device will enhance development of simulation modeling based on an improved understanding of the relationship between the biophysics of injury and neurophysiologic outcome. This will result in reduced reliance on using animals in the future.

Phase II: Produce a prototypic device that can be validated in subject animal species.
Again, all work must be humane and compliant with DoD's application of the Animal Rights Act and other federal policies regarding use of animals in research.

Phase III: Refine the device for both military and civilian markets. The device will be applicable to military research laboratories to conduct research on penetrating head injury - the leading cause of soldiers dying from wounds. The device will also need to be applicable to civilian research laboratories to conduct research on this common traumatic injury among inner city civilians and police. This device should allow research at the basic and applied levels to optimize scientific understanding of this disorder and permit preclinical testing of novel therapeutic strategies. It should also lead to future development of nonbiological simulation models of penetrating injury that do not use animal subjects.

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KEYWORDS: brain injury, trauma, head injury, traumatic brain injury, penetrating, ballistic, cavitation, gunshot, bullet, simulation, modeling