DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
SBIR 04.1 Submission of Proposals

DARPA's charter is to help maintain U.S. technological superiority over, and to prevent technological surprise by, its potential adversaries. Thus, the DARPA goal is to pursue as many highly imaginative and innovative research ideas and concepts with potential military and dual-use applicability as the budget and other factors will allow.

DARPA has identified technical topics to which small businesses may respond in the first fiscal year (FY) 2004 solicitation (FY 2004.1). Please note that these topics are UNCLASSIFIED and only UNCLASSIFIED proposals will be entertained. Although the topics are unclassified, the subject matter may be considered to be a "critical technology". If you plan to employ NON-U.S. Citizens in the performance of a DARPA SBIR contract, please identify these individuals in your proposal as specified in Section 3.5.b(7) of the program solicitation. A list of the topics currently eligible for proposal submission is included in this section followed by full topic descriptions. These are the only topics for which proposals will be accepted at this time. The topics originated from DARPA technical program managers and are directly linked to their core research and development programs.

DARPA **NOW** requires electronic submission of Cover Sheets, Technical and Cost proposals, and Company Commercialization Report. A hardcopy is no longer required. Only proposals submitted through the on-line submission site at www.dodsbir.net/submission will be accepted or considered for award. Proposals must be prepared and submitted in accordance with the DoD Program Solicitation at www.dodsbir.net/solicitation and following the instructions below.

HELPFUL HINTS:
1. Consider the file size of the technical proposal to allow sufficient time for uploading.
2. Perform a virus check.
3. Signature is no longer required at the time of submission.
4. Submit a new/updated Company Commercialization Report.
5. Please call the Toll Free SBIR Help Desk if you have submission problems: 866-724-7457
6. DARPA will not accept proposal submissions by electronic facsimile (fax) or email.

DARPA Phase I awards will be Firm Fixed Price contracts.

Phase I proposals shall not exceed $99,000, and should be a **6-month effort**. Phase I contracts can ONLY be extended if the DARPA Technical Point of Contact decides to "gap" fund the effort to keep a company working while a Phase II proposal is being generated.

DARPA Phase II proposals must be invited by the respective Phase I DARPA Program Manager (with the exception of Fast Track Phase II proposals – see Section 4.5 of this solicitation). Phase 2 invitations will be based on the technical results reflected in the Phase I draft and/or final report as evaluated by the DARPA Program Manager utilizing the criteria in Section 4.3. DARPA Phase II proposals must be structured as follows: the first 10-12 months (base effort) should be approximately $375,000; the second 10-12 months of incremental funding should also be approximately $375,000. The entire Phase II effort should generally not exceed $750,000.

It is expected that a majority of the Phase II contracts will be Cost Plus Fixed Fee. However, DARPA may choose to award a Firm Fixed Price Contract or an Other Transaction, on a case-by-case basis.

Prior to receiving a contract award, the small business MUST be registered in the Centralized Contractor Registration (CCR) Program. You may obtain registration information by calling 1-888-352-9333 and pressing 3 or Internet at www.ccr.gov.

The responsibility for implementing DARPA's SBIR Program rests in the Contracts Management Office. The DARPA SBIR Program Manager is Ms. Connie Jacobs.

SBIR proposals will be processed by the DARPA Contracts Management Office and distributed to the appropriate technical office within DARPA for evaluation and action.

DARPA selects proposals for funding based on technical merit and the evaluation criteria contained in this solicitation document. DARPA gives evaluation criterion a., "The soundness and technical merit of the proposed approach and its incremental progress toward topic or subtopic solution" (refer to section 4.2 Evaluation Criteria - Phase I), twice the weight of the other two evaluation criteria. **GOVERNMENT TRANSITION OF THE PROPOSED EFFORT IS VERY, VERY IMPORTANT. THE SMALL BUSINESS SHOULD INCLUDE THEIR TRANSITION VISION IN THEIR COMMERCIALIZATION STRATEGY. THE SMALL BUSINESS MUST UNDERSTAND THE END USE OF THEIR EFFORT AND THE END USER, i.e., ARMY, NAVY, AF, SOCOM, ETC.**

As funding is limited, DARPA reserves the right to select and fund only those proposals considered to be superior in overall technical quality and highly relevant to the DARPA mission. As a result, DARPA may fund more than one proposal in a specific topic area if the technical quality of the proposal(s) is deemed superior, or it may not fund any proposals in a topic area. Each proposal submitted to DARPA must have a topic number and must be responsive to only one topic.

Cost proposals will be considered to be binding for 180 days from closing date of solicitation.

Successful offerors will be expected to begin work no later than 30 days after contract award.

For planning purposes, the contract award process is normally completed within 45 to 60 days from issuance of the selection notification letter to Phase I offerors.

The DoD SBIR Program has implemented a Fast Track process for SBIR projects that attract matching cash from an outside investor for the Phase II SBIR effort, as well as for the interim effort between Phases I and II. Refer to Section 4.5 for Fast Track instructions. DARPA encourages Fast Track Applications ANYTIME during the 6th month of the Phase I effort. The Fast Track Phase II proposal must be submitted no later than the last business day in the 7th month of the effort. **Technical dialogues with DARPA Program Managers are encouraged to ensure research continuity.** If a Phase II contract is awarded under the Fast Track program, the amount of the interim funding will be deducted from the Phase II award amount. It is expected that interim funding will generally not exceed $40,000.

To encourage the transition of SBIR research into DoD Systems, DARPA has implemented a Phase II Enhancement policy. Under this policy DARPA will provide a Phase II company with additional Phase II SBIR funding, not to exceed $200K, if a DARPA Program Manager can match the additional SBIR funds with DARPA core-mission funds or the company can match the money with funds from private investors; or at the discretion of the DARPA Program Manager. DARPA will generally provide the additional Phase II funds by modifying the Phase II contract.

DARPA FY2004.1 Phase I SBIR
Checklist

Page Numbering

Number all pages of your proposal consecutively ______
Total for each proposal is 25 pages inclusive of coversheets, technical proposal, cost proposal and resumes
Beyond the 25 page limit do not send appendices, attachments and/or additional references
Company Commercialization Report **IS NOT** included in the page count

Proposal Format

Cover Sheet, Technical and Cost proposals, and Company Commercialization Report MUST be submitted electronically at www.dodsbir.net/submission ______

The Technical Proposal addresses

a. Identification and Significance of Problem or Opportunity ______

b. Phase I Technical Objectives ______

c. Phase I Work Plan ______

d. Related Work ______

e. Relationship with Future Research and/or Development ______

f. Commercialization Strategy ______

g. Key Personnel, Resumes ______

h. Facilities/Equipment ______

i. Consultants ______

j. Prior, Current, or Pending Support ______

The Cover Sheets were prepared on-line. ______

The Cost Proposal shows detailed cost breakout and the total cost is also listed on the Cover Sheets ______

The Company Commercialization is prepared on-line, even if your firm has no prior SBIR awards. ______

SUBJECT/WORD INDEX TO THE DARPA FY2004.1 TOPICS

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DARPA 04.1 Topic Descriptions

SB041-001 TITLE: Dual Liquid Crystal Flat Panel Display

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: The objective of this topic is to develop a technique or approach to assemble a stereoscopic display based on stacked liquid crystal displays. The proposed approach should minimize separation between the panels to prevent light leakage into adjacent pixels, reduce Moire pattern effects, and provide sub pixel alignment tolerances. In addition, the approach must accommodate a polarizer between the liquid crystal panels.

DESCRIPTION: Applications requiring remote operation of equipment abound and frequently require the operator to use a flat panel display. The disadvantage of the single flat panel display is the loss of many depth cues. This has been particularly apparent in operation of manned vehicles where the driver is forced to use a flat panel display while driving in some situations. A novel technique based on a stack of two liquid crystal panels has been proposed and demonstrated to provide stereoscopic vision in a relatively inexpensive package. One of the issues associated with this display, however, is the separation between the two displays. The physical separation induced by the glass panels and the required intermediate polarizer lead to light leakage from a pixel in one panel into adjacent pixels in the other panel. Ideally, this physical separation must be minimized such that light from a given pixel in one panel can only pass through the corresponding pixel in the next panel. For this topic, this effect will be referred to as pixel crosstalk.

PHASE I: This effort is to study the feasibility of the proposed approach to meeting the goals set forth in the objective, i.e., developing an approach or technique allowing sub-pixel alignment tolerances and eliminating pixel crosstalk between the panels. Innovative approaches are encouraged; however, all approaches must allow for the fixed polarizer between the panels and minimize the overall thickness of the stack. In addition, care should be taken not to reduce the desired 90-degree polarization rotation provided by the panels.

PHASE II: Develop the process and techniques developed in Phase I with a demonstration of a dual liquid crystal panel stack with sub-pixel alignment and minimal pixel crosstalk.

PHASE III Dual Use Applications: Scale-up to a process suitable for low cost production of the liquid crystal panel stack.

REFERENCES:
1. Kirsch, James C, Jones, Brian K, and Johnson, John L., “Compact 3D display using dual LCDs,” in Cockpit Displays X, Darrel Hopper, ed., Proceedings of the SPIE (2003).
2. Johnson, John L. and Kirsch, James C., “Flat Panel Three-Dimensional Display Unit,” U.S. Patent No 6,181,303 B1, 30 Jan 2001, http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=/netahtml/srchnum.htm&r=1&f=G&l=50&s1=6,181,303.WKU.&OS=PN/6,181,303&RS=PN/6,181,303.

KEYWORDS: Liquid Crystal Panels, Displays

SB041-002 TITLE: Fabrication Approaches for the Production of ALON Windows and Domes

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a low cost manufacturing capability for aluminum oxynitride (ALON) dome material for missiles, UAVs and other surveillance applications. Demonstrate the enhancements in the material and/or processing technology for this application that meet the desired physical/optical characteristics and that can be producible in large quantities at affordable prices.

DESCRIPTION: There is a growing need to improve the performance of Mid-Wavelength Infrared (MWIR) sensors for missiles and UAVs for enhanced target acquisition and to monitor and protect sensitive areas. One method of accomplishing this improvement is to use dual mode IR sensing techniques. Currently the dome/window material of choice for this application is sapphire, which is expensive and hard to process. An alternative material being considered due to its potentially higher transmission in the MWIR, isotropic optical properties and significantly lower fabrication cost is ALON. Approaches to improve ALON fabrication are being sought for 6 inch diameter, full hemispherical domes that exhibit better than 84% transmission at 4.5 microns and 80% transmission at 0.7 microns for a thickness of 0.180 inches. A refractive index homogeneity better than 100 ppm is being sought over the full 160-degree aperture. Enhanced fabrication approaches should utilize recent improvements and endeavor to reduce processing time, improve batch-to-batch uniformity and be scalable for generating 10,000 parts annually. Consideration should address all aspects of dome production including the quality of raw material through end polishing, with cost being a primary consideration.

PHASE I: The feasibility of fabricating ALON hemispherical domes of at least 160 degrees and 6 inches in diameter or more, which approach or satisfy the transmission properties, cited above, should be determined. This determination should consider the basic mechanical and physical properties of ALON and consider how the proposed fabrication approach can be scaled to potentially achieve desired production rates at reasonable costs. The results of the analysis shall be presented at the end of Phase I.

PHASE II: During Phase II the cost drivers for the production of large quantities of missile dome blanks must be identified and an integrated effort carried out which addresses each of these issues. At the completion of Phase II the improved process will be demonstrated by the production of prototypes that will show that the processes from batch-to-batch are consistent in both transmission and mechanical properties. It should also show that the domes possess uniformity in refractive index homogeneity better than 100ppm variation over the central 160 degrees. A preliminary production cost estimate for quantities of 1000 parts annually shall be developed, including a cost breakdown for blank fabrication and finishing. In addition, a production plan will be provided, complete with production rates, yields and projected costs.

PHASE III DUAL USE APPLICATIONS: The offeror shall provide a facility for ALON, full hemispherical dome blank production quantities that can meet full-scale Army Common Missile requirements. These blanks will be finished by the offeror, or a relationship with a finishing facility must be established to provide finished domes. It should be noted that properties for a desirable dome material also lend themselves to various commercial applications. For example, wideband transparency, high strength and hardness, and, durability and stability at elevated temperature, are appropriate for aircraft surveillance and terrorist counter-measures for homeland defense applications. Candidate materials will be evaluated upon its' applicability to various commercial applications. Special consideration will be given to those materials that are already in commercial use.

REFERENCES:
1. T.M. Hartnett and R.L. Gentilmen, "Optical and Mechanical Properties of Highly Transparent Spinel and ALON Domes," SPIE Proc. Vol. 505 (1984) 15.
2. P.C. Archibald and D.K. Burge, "Optical Measurements on Advanced Performance Domes," SPIE Proc. Vol. 505 (1984) 52.
3. E.A. Maguire, J.K. Rawson, and R.W. Tustison, "Aluminum Oxynitride's Resistance to Impact and Erosion, SPIE Proc. Vol 2286, (1994) 26.

KEYWORDS: Missile Domes, Aluminum Oxynitride, ALON, Midwave Materials

SB041-003 TITLE: <u>Multicasting in Mobile Wireless (Ad Hoc) Networks</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Design a prototype network and physical layer technique that exploit differences due to node capability, propagation characteristics, etc. in a mobile, wireless (ad hoc) network by simultaneously delivering different messages to nodes of different capabilities. Evaluate the improvement in performance under diverse scenarios of the joint design of the physical layer and network layer protocols relative to separate designs.

DESCRIPTION: In mobile, wireless (ad hoc) networks, the channels between the nodes may differ greatly because of differences in propagation and interference, and due to the differing capabilities of the nodes themselves. For example, some nodes may have directional antennas which have the potential to substantially improve the performance of wireless mobile ad hoc networks (MANETs). A significant limitation of existing communications technology is that current transmissions are designed for either broadcast reception or reception by a single other node. The differences in the communication channels are ignored and directional antennas are rarely considered. In order to significantly improve the capacity, knowledge of the channel conditions and node capabilities must be exploited. Multiresolution signaling techniques have been used to show that it is practical to perform simultaneous transmission by modifying the modulation or coding. However, these techniques have not been extended to prove their utility in a mobile, wireless (ad hoc) communications network. Furthermore, the practicality of these techniques has not been proven through implementation. In relation to directional antennas, to efficiently implement multicasting, the network protocols may need to form multiple beams or simply a wide beam to reach a set of intended receivers by adaptive beamforming. Adaptive beamforming can create multiple beams towards all intended receivers, but the peak gain for each beam changes dramatically depending on how the receivers are spread around the transmitter. A power control mechanism is therefore essential to give each receiver enough signal to interference-plus-noise ratio (SINR) for the signal reception; however, transmit power control is itself a significant challenge in MANETs, as unlike cellular networks, the network does not typically have the means to obtain immediate feedback from receivers. In the case of mobile, wireless (ad hoc) networks, the implementation of multicasting or simulcasting techniques will require changes to the physical, link, and network layer protocols. Cross-layer design techniques that develop protocols can appropriately exploit the advantages of and overcome the unique challenges presented by adaptive beamforming antennas and modulation techniques to improve the performance of multicasting protocols as needed.

PHASE I: Create a feasibility concept and simulate the multicasting/simulcasting, taking in to account both omni and (smart) directional antennas, showing how this technique can effectively improve the efficiency of communications in mobile, wireless (ad hoc) networks, including identifying necessary changes in the physical, link, and network layers. The feasibility study should jointly consider the different layers.

PHASE II: Develop a prototype system that demonstrates the effectiveness of digital simulcasting in a small wireless communications network in diverse operational scenarios. Demonstrate scalability in simulation of the protocol as a function of multicast group size, user traffic, network size, and mobility patterns.

PHASE III Dual Use Applications: The technology developed under this SBIR can be applied to both military and commercial communication systems. Commercial use of smart antennas in cellular and community access networks is growing. Multicast protocols that can exploit smart antenna technologies have the potential for widespread use for applications including second and third-generation cellular communication systems.

REFERENCES:
1. M. B. Pursley and J. M. Shea, “Nonuniform phase-shift-key modulation for multimedia multicast transmission in mobile wireless networks,” IEEE Journal on Selected Areas in Communication, vol. 17, no. 5 pp. 774–783, May 1999.
2. Jeffrey E. Wieselthier, Gam D. Nguyen, and Anthony Ephremides. Energy-Limited Wireless Networking with Directional Antennas: The Case of Session-Based Multicasting. In Proceedings of IEEE INFOCOM 2002, New York, NY, June 23--27 2002, http://www.ieee-infocom.org/2002/papers/303.pdf.

KEYWORDS: Mobile Wireless (Ad Hoc) Networks, Digital Modulation, Error-Control Coding, Directional Antennas, Smart Antennas, Multicasting, Simulcasting, Cross-Layer Design

SB041-004 TITLE: Cascading Unmanned Undersea Vehicles

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a means to autonomously launch and recover a small unmanned undersea vehicle (UUV) from a large UUV.

DESCRIPTION: UUVs have gained acceptance for mine reconnaissance missions and are being considered for many more maritime applications. The concept of having cascading UUV vehicles (using a large UUV to transport several smaller UUVs to the desired area of operations where they are launched, recovered, and recharged) has been proposed for several mission applications. However, such a concept has yet to be demonstrated and must deal with several difficult factors including:
o Low power, low complexity mechanisms for autonomously launching the small UUVs
o Hydrodynamic effects at low speeds (2-4 knots) during the recovery phase
o Guidance sensors for rendezvous and docking
o Mechanisms for autonomous, low-speed, reliable docking

This SBIR focuses on developing a minimum power launch and recovery system for small UUVs (2-3 feet long; 4-6 inches in diameter) from a large UUV (21 inch diameter).

PHASE I: Design a feasibility concept for a launch and recovery system to include a sensor system for guiding the small or large UUV into position for recovery. The following are notional requirements:
o Launch and recovery depth: 10 - 100 meters
o Launch sequence: Selective – any small UUV vehicle on command
o Launch rate: 1 every 4 minutes (includes opening and closing of access doors)
o Minimum number of small UUV vehicles: 4
o Recovery speed: Large UUV 2-6 knots/small UUV 2-4 knots
o Recovery rate: At least 1 every 15 minutes (starts when vehicles are within 10 meters of each other).

PHASE II: Fabricate and demonstrate the launch and recovery system, including connections for data transfer and power recharge. This may be performed on a surrogate host platform simulating the large UUV.

PHASE III DUAL USE APPLICATIONS: The final system demonstration involving a full size UUV platform launching and docking a small UUV will be accomplished during this phase with a commercial or government sponsor. The technology developed under this SBIR can be used in all commercial UUV applications that require the launch and recovery of smaller UUV devices.

REFERENCES
1. Fletcher, Barbara, "UUV Master Plan: A Vision for UUV Development", Space and Naval Warfare Systems Center D744, website address: http://www.spawar.navy.mil/robots/pubs/oceans2000b.pdf
2. "The Navy's Unmanned Undersea Vehicle Master Plan", April 20, 2000, website address: http://www.auvsi.org/resources/UUVMPPubRelease.pdf
3. "Navy UUV Master Plan: A First Step Toward A Vision of Dominance via Unmanned Systems", website address: http://www.npt.nuwc.navy.mil/UUV/default.htm
4. Caccia, M. and Ricerche, C. N., "Vision for Estimating the Slow Motion of Unmanned Undersea Vehicle", website address: http://www.robotlab.ian.ge.cnr.it/caccia/pdf/natogrant.pdf

KEYWORDS: Cascading UUVs, Launch, Recovery, Guidance Sensors

SB041-005 TITLE: Shipping Container Remote Sensing

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors, Electronics, Battlespace

OBJECTIVE: Research and development on remote sensing inspection/assessment technologies that will revolutionize security measures by screening in-bound shipping containers for materials such as biological warfare disease pathogens, toxic chemicals, explosives, and nuclear or radioactive materials. Such technologies should be able to be used in offshore holding areas for inbound container ships.

DESCRIPTION: Each year over sixteen million containers arrive in our country by truck and in container ships. Current inspection regimes rely on manual inspection procedures and on x-raying, on gamma ray inspection technology, and on use of radiation detectors on containers of interest. Rarely can more than a small percentage of the total number of containers in a container ship be adequately inspected, and any uninspected container can pose significant risk.

Areas of interest include: (1) sampling methods that include the use of controlled biological or biological-like systems, to search within shipping containers (2) instrumentation for large-scale, rapid, remote screening; (3) passive and active techniques that have the potential to detect undesirable, dangerous, illegal, or unauthorized materials, such as biological warfare disease pathogens, unauthorized toxic chemicals, explosives, and nuclear or radioactive materials within shipping containers; (4) Micro-electromechanical Systems (MEMS) based technologies to enable ultra-miniaturization of mechanical components and their integration with microelectronics with specific focus on developing integrated, micro-assembled, multi-component sensor systems with low false alarm rates; and, (5) unattended shipping container inspection technologies that can passively exploit pre-existing procedures for off-load, on-load, or movement, and transfer of shipping containers.

Proposing companies have significant flexibility in formulating its approach to meeting the technical goals; innovative or creative approaches to meeting the technical goals are desired.

PHASE I: Develop a methodology to remotely measure, sense or assess the contents of a standard shipping container either in transit or in port. Demonstrate proof-of-principle through analysis or experimentation.

PHASE II: Design, fabricate and demonstrate a remote sensing capability including a double-blind test.

PHASE III Dual Use Applications: The technology developed under this SBIR will have commercial diagnostic and control applications.

KEYWORDS: Remote Sensing, Sampling Methods, Modeling and Simulation

SB041-006 TITLE: Distributed Maritime Vessel Tracking

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Research and development of remote sensing technologies enabling novel methods for tracking, localization, and identification of commercial maritime vessels.

DESCRIPTION: This will allow development of an understanding of vessel operation under dynamic conditions and allow assessment of behaviors of maritime vessels. If successful, this effort will assist in protecting critical bases of operation and ports from terrorist attack. Significant technical challenges include:

Autonomous target recognition and classification;
Persistence and ubiquity;
Operation in heavy seas and weather;
Unit collaboration and deconfliction.

Areas of interest include: (1) dispersion and management technologies; (2) Micro-electromechanical Systems (MEMS) based technologies to enable ultra-miniaturization of mechanical components and their integration with microelectronics with specific focus on developing integrated, micro-assembled, multi-component sensor systems with low false alarm rates; and, (3) Networking and communications technologies. Tags developed by other programs may be used but are not the focus of this effort.

Proposing companies have significant flexibility in formulating its approach to meeting the technical goals; innovative or creative approaches to meeting the technical goals are desired.

Applications: Envisioned applications include noncooperative identification of commercial shipping to identify and monitor pirated traffic.

PHASE I: Develop a design for a system capable of autonomous sensing, tracking and localization of maritime vessels in a distributed environment. Demonstrate proof-of-concept through analysis and experimentation.

PHASE II: Design, fabricate and demonstrate capability in relevant environment.

PHASE III Dual Use Applications: The technology developed under this SBIR will have commercial diagnostic and control applications.

KEYWORDS: Remote Sensing, Sampling Methods, Modeling and Simulation

SB041-007 TITLE: Integrated Optical Bus Interface Module

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop an integrated chip-scale optical interface module that provides military platforms with a high speed and low-cost all optical network. The interface module will have sufficient dynamic range to be capable of transmitting high-speed digital data as well as high frequency, broadband RF analog signals such as radar and video.

DESCRIPTION: The proliferation of data, voice, and video communications has strained the capacity of conventional networks and motivated research on all-optical networks. It is now clear that wavelength division multiplexing (WDM) and optical switching are the best approach to future networks. However, most research has focused on long haul, and the adaptation of networks to aircraft and other military platforms has not received much attention. What is needed is new, lower cost, chip-scale interface modules for optical communications on military platforms. These include modules for high-speed digital data but also for RF signals with low noise figure and high spurious-free dynamic range. The interface modules need to support a wide variety of sensor and control signals, and the associated network architecture should lack single point failure components and needs to provide redundancy for very high reliability networking. The interface modules need to provide the capability of amplifying the optical signals to compensate for optical signal splitting and other losses and the modules need to support the scaling of data to larger capacity such as a WDM approach. Such modules would provide a notable advantage in smaller size, lower manufacturing cost and increased reliability compared to current discrete component approaches.

PHASE I: Develop a chip-scale optical interface module design, and perform feasibility investigations. Phase I should also define the network architecture to be used with the interface modules and demonstrate the feasibility of high-speed digital and high spurious-free dynamic range RF communications.

PHASE II: Fabricate and test integrated optical interface modules and demonstrate their performance in a laboratory optical network. Testing with a military systems integrator is highly desirable and would provide a large incentive for further development after the end of Phase II.

PHASE III DUAL USE APPLICATIONS: The integrated optical interface modules that are developed under this SBIR topic are also applicable to civilian aircraft and ships as well as to campus scale local area networks. The use of these integrated optical interface modules in civilian applications will benefit the military, as the economies of scale will tend to lower the cost of the interface modules.

KEYWORDS: Chip-Scale Optical Interface Module, Wavelength Division Multiplexing (WDM), WDM, Optical Switching

SB041-008 TITLE: Advanced Rectenna Technologies for Space Power Applications

TECHNOLOGY AREAS: Space Platforms, Weapons

OBJECTIVE: Develop and demonstrate advanced rectifying antenna (rectenna) technologies for enabling wireless power transfer to future military space platforms.

DESCRIPTION: This topic is focused on advanced rectenna technologies that will address the power requirements for future military space platforms. The development of advanced space power technologies will be essential in order to meet the needs of future commercial and DoD space systems. In many cases, the power requirements for future space applications currently being considered far exceed the state-of-the-art power systems that are currently deployed. For example, it is anticipated that achieving the capability to maneuver from Low-Earth Orbit (LEO) to Geostationary Earth Orbit (GEO) using electric propulsion will require a minimum of 100 kW of electrical power. Directed energy weapons such as a spaced based laser are anticipated to require up to 1 MW of power for operation. The current approach for providing power to space platforms combines both energy conversion (i.e. solar panel or Radio-Isotope Thermoelectric Generator (RTG) technologies and energy storage (i.e. batteries, capacitors) technologies. This SBIR topic considers a paradigm shift in providing power by exploring the possibility of generating power remotely and delivering power to one or more space platforms via microwave transmission. Although the idea of microwave power transmission is not new, the implementation of this technology for space applications has been prohibited due to a number of issues including: 1) the need for large aperture antennas for the efficient collection and transmission of rf energy; 2) the need for novel thermal management approaches for efficiently dissipating waste heat; and 3) the need for efficient rectification of microwave energy at frequencies above 100 GHz.

PHASE I: Prepare a feasibility study for a notional wireless power transfer system that would be capable of delivering 100 kW to 1 MW of electrical power to a space platform. As part of this case study, successful performers are expected to provide a detailed description of the necessary rectenna performance requirements. Based on these requirements, performers will provide an assessment of the potential for developing such a rectenna system. In particular, performers will identify and quantify the “breakthroughs” in performance for the individual sub-components (antenna, diode, and thermal management) necessary for achieving the overall required rectenna performance.

PHASE II: Performers will pursue an integrated, multidisciplinary approach towards designing, fabricating, and demonstrating proof-of-concept for achieving the required antenna, diode, and thermal management performance necessary for enabling the “notional” Phase I rectenna system. Proof–of-concept constitutes a laboratory demonstration of sub-component performance at 100 GHz or higher and does not require integration into a fully functional rectenna system.

PHASE III Dual Use Applications: The technology developed under this SBIR can be used in future commercial satellite platforms. The ability to provide power remotely will allow for greater payload and/or significant monetary savings as up to 25% of current spacecraft weight is dedicated to generating and storing electricity.

REFERENCES:
1. “The History of Wireless Power Transmission”, William C. Brown, Solar Energy 56 #1, p 3-21, 1996, http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V50-3VV72CR-B&_user=10&_handle=W-WA-A-A-AW-MsSAYVA-UUA-AUCCUAUEUC-YYUYVBUY-AW-U&_fmt=summary&_coverDate=01%2F31%2F1996&_rdoc=2&_orig=browse&_srch=%23toc%235772%231996%23999439998%2363535!&_cdi=5772&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=780a11fc15db59656c1af09c00c76393..

KEYWORDS: Rectenna, Wireless Power Transfer, Space Power

SB041-009 TITLE: IQs for Avatars: Testing and Editing Intelligent Agents for Training

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: The objective of this work is to develop methods to create, edit and assess the performance of intelligent agents for training systems.

DESCRIPTION: To succeed, the Secretary of Defense’s military transformation initiatives will require a parallel training transformation. The training burdens are growing as new systems and procedures demand more cognitive performance from our warriors, as well as from maintenance, intelligence and support providers. Often there are few if any experts available who can become conventional instructors. Moreover, the new degree of coordination among individuals and units that the transformation demands requires much more team training. It is costly, and often impossible to bring the people who need training together long enough and often enough to develop warfare skills adequately.

Advances in readily available computers, networking and in the commercial gaming regime (both on-line and off) suggest that virtual training environments could make a major contribution to the solution to these issues. DARPA, for example, has initiated a program to create PC-based cognitive training in several areas and tie them together into universal, persistent, on-demand training wars. This approach is effective only if the virtual training environment can replace scarce and costly humans with avatars and intelligent agents (also called non-player characters (NPCs), in the commercial computer gaming world). Those avatars and NPCs must be believable to the trainee within the context of the training system or simulation. At the moment, however, there is no assessment measure or IQ test for the utility of an intelligent agent. In addition, it must be easy and cheap to populate a virtual training environment with such agents, and to alter the behavior of a "stock" agent to represent different cultures and circumstances.

PHASE I: In Phase I the performer will define how to assess the believability of NPCs in training contexts. This is not a simple task. Even Bullwinkle, the cartoon moose, is believable in some contexts whereas an almost human representation of a character in a simulation may fail to work when it doesn't quite meet the expectations for reality that its initial appearance suggests. The key measure is not whether the avatar looks, acts and walks like a human, but how well it works in a training context to support learning. A second Phase I objective is the initial defining of how to insert new cultures into avatars without having to remake the entire character. For example how a crowd in a training game could be changed easily from an angry assembly in Afghanistan to a docile gathering in Bosnia or a curious crowd in Korea? This work must be aimed to work on low cost, widely available computing and display platforms like personal computers.

PHASE II: Phase II will develop and implement the procedures defined in Phase I. The performer will apply its avatar IQ tests to NPCs in various complicated military simulation games including those in DARPA's DARWARS projects. The performer will also show how avatars can be created and inserted into several training contexts (not necessarily of their own making) with the ultimate goal that training games can be populated by effective non-player characters at low cost and this process can be performed by relatively unsophisticated users, not specialists.

PHASE III Dual Use Applications: Adult education in this country is a huge problem being addressed piecemeal. Every new training system is created with little reference to past successes and failures. Standardized tools and techniques for inserting NPCs into training systems should make it possible to create new, effective training quickly and cheaply. There is a large market for this kind of training for first responders in the homeland defense arena.

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KEYWORDS: Training, Intelligent Agents, Avatars Non-Player Characters

SB041-010 TITLE: Conducting Ionic Materials for Solid State Air Breathing Engines

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Design and demonstrate the use of solid state oxygen anion conductors for compression of oxygen in high altitude air breathing engines.

DESCRIPTION: The efficiency of mechanical compressors of gas turbine engines are inefficient at high altitude due to high compression ratios and associated adiabatic heating. The use of oxygen conducting ionic solid state pump may allow higher altitude operation without the penalty associated with carrying an oxidant (~3.5 pounds of oxygen required per pound of fuel). Altitudes above 100 thousand feet are of interest to take advantage of reduced drag which will enable higher speed. Mass transport of oxygen and operating temperature of the oxygen pump will be important factors in the design configuration of the engine. Oxygen conduction ceramics1, 2 are available but require operating temperatures above ~600o C which may require integration into the combustion liner of the engine. Structural integrity of a ceramic oxygen pump in an engine environment will require an innovative design. Development of a new class of non-hydrated polymer membranes which operate at lower temperatures may be feasible and would allow for larger surface area design possibilities for collection of oxygen.

Note: hydrated polymer materials may be limited to lower current densities and operating temperatures due to electrolysis or evaporation of water.)

PHASE I: Prepare a feasibility study for solid state compressors for air breathing high altitude engines. Determine the scalability of the design concept(s) for a range of engine sizes, thrust levels, altitudes, and vehicle speeds. Determine availability of materials and material fabrication capabilities and conduct any material characterization measurements if needed for design. Produce a preliminary design for Phase II along with a test stand protocol for the engine.

PHASE II: Design, build and evaluate a small engine with a solid state compressor. The instrumented test stand evaluation results will be used to determine the validity of the feasibility study predictions prepared in Phase I. On board electrical power generation should be considered in the design of a flight ready engine but need not be incorporated in the test stand demonstration engine.

PHASE III Dual Use Applications: Design capabilities developed may be useful for single stage to orbit vehicles for both commercial and military payloads. Higher altitude platforms may also be used for communication nodes and sensor platforms. The solid state compressor technology may also be applied to low NOx/high power density engines. The oxygen conducting membranes may also be used for oxygen enrichment of air for medical use or for electro-catalysis for oxidation/reduction reactions.

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KEYWORDS: Gas Turbine, High altitude, Oxygen conductor, Compressor

SB041-011 TITLE: Data Structures for Efficient and Integrated Simulation of Multi-Physics Processes in Complex Geometries

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop new and advanced abstract data types (ADT) including data structures and access and manipulation methods allowing highly efficient access to local geometrical information and data transfer between algorithms to support large-scale, multi-processor simulation of multi-scale and multi-physics processes in complex geometries.

DESCRIPTION: Computer simulations across numerous defense application areas, including computational fluid dynamics and electromagnetics, increasingly involve multiple physical processes, a broad range of temporal and spatial scales, and intricate geometries. Simulations based on numerical solution of differential equations entail both local and aspects: numerical approximation of derivative at a point requires only local neighbor access and local coordinate metrics, while capturing larger-scale geometry and global topology of a problem domain requires encoding of boundary conditions and non-local propagation of information; e.g., via time-evolution or iterative relaxation.

Current practice for multi-process simulations generally synthesize complex scenarios from simple parts, combining algorithms developed for single-process, single-scale, simple-geometry applications. This approach has the drawback that the underlying data structures borrowed from tamer situations typically fail to simultaneously address the need to consider both local and global data management issues. The results often include highly undesirable artifacts, such as rigid inconsistent global topology and boundary descriptions, impediments to adaptive mesh refinement, highly inefficient data transfer and synchronization between algorithm components addressing the individual physical phenomena. Furthermore, data structure issues tend to make parallelization difficult.

This topic seeks to identify and develop innovative data structures and libraries to support PDE-based (partial differential equation) simulation algorithms that address the issues just described. In particular, these data types should enable large-scale parallel simulations of multi-physics processes across a wide range of spatial and temporal scales and taking place in complex geometrical and topological domains.

PHASE I: Produce a detailed feasibility analysis for the candidate ADT, including interface, access and manipulation methods, software library structure, and performance trade-offs. Develop a plan for validation and demonstration of the ADT, suitable for execution in Phase II, which incorporates a focus application of DoD significance.

PHASE II: Implement a prototype data management software library based on the ADT to support parallel multi-scale, multi-physics simulations in the presence of complicated geometry and topology. Demonstrate and validate the ADT in the context of a DoD-relevant focus application.

PHASE III Dual Use Applications: Success in this undertaking has broad potential for impact in both military and civilian applications. Applications with primarily military impact include:
- Electromagnetic scattering simulation for low-observable vehicle design
- Joint electromagnetic and fluid dynamic design of structures

Additional applications with substantial civilian and commercial potential include:
- Fluid dynamics simulation for aerodynamic/hydrodynamic vehicle design
- Particle simulation for modeling the deposition of materials in microelectronics fabrication
- Meteorological simulations
- Simulation of epidemics, spread of fires, and failure dynamics in complex systems
- Visualization of dynamic processes

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KEYWORDS: Data Structures, Simulation, Computational Electromagnetics, Computational Fluid Dynamics

SB041-012 TITLE: Non-Invasive Physiological Monitoring

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop non-invasive physiological monitoring technologies for examining the physiological status of war fighters.

DESCRIPTION: Research and development of innovative solutions towards the development of miniaturized components and unobtrusive devices that are capable of continuous physical health monitoring of an individual on the battlefield. The technologies being sought will operate without having the need to extract or contact bodily fluids. Such innovative solutions may be based on radio frequency, ultrasonic or optical based spectroscopy. Alternative novel approaches, however, are encouraged. For achieving diagnostics in such a manner, low power devices that may be directly interfaced onto the individual or integrated into the war fighter's uniform or gear will be considered. The ability to measure more than one physiological marker (i.e. glucose, lactate, C-reactive protein, cytokines, white blood cells, etc.) or possibly, gene or protein expression in-vivo is strongly encouraged. The biological markers selected may not only provide insight into the health status, but also address pre-symptomatic activity due to infection, chemical or biological agent exposure. Measurements of physiological targets beyond glucose is strongly desired. Device technology for continuous, non-invasive methods of screening multiple vital signs, such as pulse, blood pressure, heart rate and respiration, in addition to the previously mentioned targets will also be considered. Additional efforts in device technology include the advancement of methods for signal processing, integrated, compact addressable detection techniques, low-power components, high-performance microfabricated components and schemes for performing multiplexed measurements.

PHASE I: Develop proof-of-concept computer simulation and prepare a feasibility study to develop a design for a prototype device and comparison with state-of-the-art technologies.

PHASE II: Demonstrate a non-invasive physiological status monitoring device that is capable of continuously diagnosing multiple protein markers and/or vital signs in an individual.

PHASE III Dual Use Applications: Technologies developed under this topic will be the basis for devices worn on soldiers to monitor physiological signatures for early detection of bio-warfare agent exposure, triage of bio-events and vital signs monitoring. Furthermore, medical personnel may be able to monitor a war fighter remotely via non-invasive means. Commercial applications are most relevant in monitoring glucose, treatment in intensive care units and medicine efficacy.

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KEYWORDS: MEMS, BioMEMS, Non-Invasive Physiological Monitoring

SB041-013 TITLE: Real Time Monitoring of Signaling Pathways in Biological Cells

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical, Electronics, Battlespace, Nuclear Technology

OBJECTIVE: This topic seeks innovative research into the development and demonstration of novel concepts that use nanoscale probes (nanoparticles, nanotubes, etc.) to enable the real-time observation and data acquisition on signaling pathways in biological cells that are activated in response to specific stimuli.

DESCRIPTION: Studies of signaling pathways in biological cells have led to better understanding of cellular responses to various disease causing agents (virus, bacteria, etc.) and are resulting in better treatment alternatives in the form of drugs that target specific pathways. However, most current studies of cellular mechanisms rely on a black-box approach, in which probes external to the cell are used to monitor cellular outputs in response to specific inputs. A limited number of events have also been monitored within cells using fluorescent molecules. However, a detailed, real-time 'inside-look' at cellular pathways has not been achieved due to significant challenges in using appropriate probes that can report on multiple events (in real time) without interfering with cellular activity.

The objective of this research is to investigate in-situ nanoprobes that enable the real-time observation of various cellular events such as molecular binding to cellular receptors, release of second messengers, gating of ion channels, gene expression and Messenger Ribonucleic Acid (mRNA) production, protein synthesis, etc. Innovative ideas are needed for the functionalization and deployment of nanoprobes that accomplish this goal without disrupting the normal functioning of the cell. If successful, this research will lay the foundation for technologies that will enable an 'inside-look' at cellular signal processing as opposed to the limited input-output experiments that are used currently to study cells. Once the pathways are elucidated, it is anticipated that these nanoprobes could be potentially used to interrupt and control transcription pathways in response to specific events.

Ongoing research in nanotechnology is starting to demonstrate controlled fabrication of high quality nanostructures (nanoparticles, nanotubes, nanopores, etc.) that are capable of interacting with biology at the molecular scale. Recent breakthroughs in developing nanoprobes have demonstrated the use of nanoparticles and semiconductor quantum dots as highly stable and effective reporters of cellular events. It is anticipated that these developments will lead to new kinds of nanoprobe technologies that enable detailed real-time analysis of single cells.

PHASE I: Investigate the placement of nanoprobes into biological cells to study signaling pathways. Explore appropriate engineering and bio-conjugation of these probes to detect specific molecular targets within cells in a non-intrusive manner. Study and quantify data/signal acquisition from activation of specific molecular events within the cell. Demonstrate feasibility of using nanoprobes for high SNR (Signal-to-Noise Ratio), real-time transduction of cellular signals.

PHASE II: Develop placement technologies for incorporating multiple nanoprobes into cells at various locations to track sequences of events in the signaling pathway. Verify and validate signaling pathways using data from previous input-output experiments as well as models. Demonstrate real-time, programmable control of cellular events using the probes. Demonstrate operation, stability and controllability of the nanoprobes and quantify performance metrics.

PHASE III Dual Use Applications: The capability to monitor biological cells in real time will enable the use of cells as highly sensitive and selective bio-sensors for biological/chemical agents, health monitoring and disease prevention. The ability to better understand and control signaling pathways will result in novel drugs and therapeutic methods to treat diseases and infections.

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KEYWORDS: Biological Cells, Signaling Pathways, Real-Time Analysis, Nanoprobes, Quantum Dots, Nanoparticles, Optical Addressability, Signal Processing, Biological/Chemical Sensors

SB041-014 TITLE: Pre-Health Seeking Behavior

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

OBJECTIVE: This topic seeks innovative research to identify, characterize, and validate the aggregate behaviors of people who exhibit symptoms of flu-like illnesses, prior to the point at which these people would begin to seek medical care. Behaviors are a response to symptoms, and these flu-like symptoms correspond to the symptoms likely to be associated with biological pathogens. Having an accurate characterization of such behaviors would allow the identification of data sources that would provide early indication of a naturally occurring or deliberately released biological outbreak against military or civilian populations In particular, because military personnel in CONUS are not separated from civilians, a biological attack whose purpose was to degrade US force readiness or to target US military assets for other reasons would also infect civilians. The attack might be detectable first in the civilian population due to its larger numbers and its greater proportion of high-risk (e.g., elderly) individuals.

DESCRIPTION: The project will determine with high confidence the behaviors that people exhibit from the time they begin to exhibit symptoms after they have been exposed to naturally-occurring pathogens up until the time they seek medical care, along with an analysis of which conditions and severities would make it more likely for those starting to present symptoms to actively seek medical care. These behaviors could include purchases of over-the-counter remedies, changes in daily activities or schedules, different uses of utilities, seeking out health information, etc. Different groups of people might behave differently, and the same people might behave differently depending on various contextual variables such as weekday/weekend, school holiday, etc. Factors that affect these behaviors would be determined and distributions of behaviors based on these factors would be identified. These distributions would be both cross-sectional (i.e., dependent on demographic, geographic, climatic, and/or other factors) and temporal (i.e., reflecting the fact that different people respond to symptoms at different times). The purpose is to create an analytical basis on which to appropriately and effectively identify and monitor existing data streams for changes in aggregate behaviors that would indicate and localize an outbreak of disease. Differences in responses by military and civilian personnel would be identified to determine which population's indicators provide the earliest possible detection of an attack that affects both.

PHASE I: Conduct a literature review of known behaviors of people with early symptoms for influenza-like illness. Use appropriate methodologies to determine behaviors of infected people up until they enter the medical provider system. Such methods may include but not be limited to: surveys; focus groups; market research; modeling; analysis of available data, etc. Ensure complete anonymity of any participants, and full compliance with all applicable privacy laws, regulations, and policies.

PHASE II: Validate results of Phase I by using independent samples or populations. Confirm that results apply in multiple locations and are consistent over time. Identify population subgroups that may engage in specified behaviors earlier than others and could serve as a sentinel population, especially factors unique to military personnel. Obtain actual data sets of the types identified in Phase I and validate that they co-vary with historical natural disease outbreaks and determine lead times over patient presentations to medical providers. Identify any confounding factors. Ensure complete anonymity of any participants, and full compliance with all applicable privacy laws, regulations, and policies.

PHASE III Dual Use Applications: The technology developed under this SBIR can be used to predict civilian outbreaks of disease and be used by health providers to predict demands on their services during natural disease outbreaks in order to balance loads and streamline services while assuring appropriate coverage in their facilities. This is in addition to the primary use, which is to provide force protection to military personnel based on an attack that targets military personnel who may be intermixed with the civilian population.

KEYWORDS: Biosurveillance; Disease; Anthrax; Terrorism; Influenza

SB041-015 TITLE: Visualizing the Asymmetric Environment

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop and validate a tool to support visualization of the asymmetric environment incorporating geographical information and terrorist event data containing infrastructure information (transportation, security, government, military, cultural, demographic, etc). The ability to better visualize the complexity of the asymmetric environment will augment the current planning and course of action generation capability.

DESCRIPTION: The U.S. and our allies are currently involved in asymmetric conflict throughout the world. Today's planning applications typically support the visualization of information tuned to more conventional, maneuver oriented warfare environments, displaying basic geographic, atmospheric, force structure, movement information over time. In today's asymmetric environment, the information space is more complex and dense, including the above information as well as less traditional information such as infrastructure, cultural, and demographic specific information. Research advances in the area of Geographical Information Systems, data mining, data mining technologies potentially support the rapid fusion of these seemly disparate information associated with the asymmetric environment into a single visual environment. However, there still remain some significant challenges differentiating the visualizing of an asymmetric environment. Technology shortcomings include geographic profiling, pattern extraction, and behavior modeling required to develop visualization tools tuned to the asymmetric environment. In an effort to meet the objective of this SBIR, research may draw upon existing models, architectures, and techniques or create new ones. However the approach should yield a significantly enhanced capability in the following areas: real-time group specific target analysis, trend analysis, and automated projection of these signatures against U.S. assets.

PHASE I: Prepare a feasibility study to develop a concept design for a visualization tool tuned to the asymmetric environment, to include the projected data requirements, functional flowchart, and system design. Specify the data requirements to demonstrate the tool against a recent set of historical attacks.

PHASE II: Develop and demonstrate a prototype visualization tool populated with the requisite geographic and terrorist event data (transportation, security, government, military, cultural, demographic, etc). The implementation must include complete documentation to allow for direct replication of methods and results across each group.

PHASE III Dual Use Applications: The development of a visualization tool for asymmetric attacks will support DoD's and the Intelligence Community's planning process as well as provide the same benefit for more commercial applications such as law enforcement (security agencies such as FBI, DEA, and Secret Service), municipal planning, emergency management response (FEMA), international corporations, and non-government organizations (Red Cross).

KEYWORDS: Force Protection, Geographical Profiling, Geographical Information Systems Data Mining, Pattern Extraction, Human Behavior Representation

SB041-016 TITLE: Generating Security Policies for Black-Box Software via Collaborative Execution Monitoring

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: This program seeks to securely use distributed monitoring to learn about the behaviors of widely-used programs, and to use this knowledge to evolve increasingly useful security policies for the systems that participate in the monitoring.

DESCRIPTION: A key tenant of effective security is the Principle of Least Privilege, first articulated by Saltzer and Shroeder in 1975. This principle asserts that each active element of a system (e.g., running program) should be given the minimum access rights needed to accomplish its task. Achieving this in practice has been extremely rare for two reasons. First, access rights, as represented by Access Control Lists (ACLs), user identifiers, groups, protection bits, etc., are low-level in nature, complex, and notoriously difficult to write and validate. Second, understanding a program's access requirements in the first place is equally labor intensive and error prone, and all but impossible if the program is provided without source code, i.e., "black box." Giving programs unneeded access rights is problematic because that increases the damage that might occur if a program is compromised. Giving programs insufficient access rights can deny service and can also destabilize a program, making it both less functional and less secure.

This DARPA program seeks to address these challenges by developing collaborative monitoring tools and techniques to automatically generate increasingly-comprehensive composite program behavior profiles, and to use the profiles as input to simplify the security configuration task and, over time, to gradually increase confidence that access rights are properly set to allow legitimate program behaviors, but not more. Thousands, or even millions, of instances of a widely-used application may be in operation at any moment. Using collaboration techniques analogous to those of SETI@home and distributed.net, this DARPA program seeks to automatically and securely share information about widely-used programs to construct increasingly comprehensive profiles, and to then make these profiles available to participants. Such sharing, however, raises a number of security issues and practical management issues.

PHASE I: This phase will determine the feasibility of securely performing execution monitoring on participating systems spread throughout the Internet, sharing an appropriate abstraction of the information learned on different systems that provides useful behavioral information without compromising the privacy of any participant, and detecting invalid information submitted by possibly malicious participants.

PHASE II: This phase will develop prototype tools for conducting the distributed monitoring, for combining resulting behavior profiles, and for assisting administrators in configuring access rights on either a Linux/Unix or a Windows platform. This phase will furthermore conduct an experiment to measure, to the extent possible, the effects of behavior aggregation on the accuracy of the generated security policies.

PHASE III Dual Use Applications: This technology could be used in a broad range of military and civilian applications, e.g., the Defense Information Infrastructure Common Operating Environment (DII COE), situational awareness systems, logistics systems, intelligent office assistants, etc.

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KEYWORDS: Learning, Information Processing, Security, Software Development

SB041-017 TITLE: <u>Analysis of Classical and Quantum Information Interface Requirements (ACQuIIRe)</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: To develop hardware and software needed to integrate a quantum information system into an existing fielded network or computing system.

DESCRIPTION: As efforts move forward on all of the fundamental components of a working quantum information system, integration of quantum information with classical information systems is becoming increasingly important. In particular, quantum communications technologies such as Quantum Key Distribution (QKD) systems are close to the maturity level required for transition into a Joint Services Acquisition Program. The technology demonstration required for a successful transition will require seamless interfaces between the quantum systems under development and existing classical information systems.

Work conducted under this SBIR topic will develop the interfaces needed to demonstrate joint operation of quantum and classical information systems. These may include the interfaces to classical networks, signal acquisition hardware and operating systems.

PHASE I: Analyze the possible interfaces between a quantum information system and a classical network or information system. Identify potential risk areas as well as strong candidates for demonstration hardware and software. Propose modifications to current quantum and classical systems that would facilitate insertion of a quantum information component into a classical system such as an existing network.

PHASE II: Develop a prototype hardware/software system that would aid in the demonstration of an information system that integrates quantum and conventional technologies.

PHASE III Dual Use Applications: Quantum communication systems are of potential use to both the DoD and the private sector to enhance communication security. Quantum computing systems may provide rapid solutions to difficult computational problems. The hardware and software interfaces developed under these awards will accelerate the use of quantum information systems.

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KEYWORDS: Networks, Quantum Communication, Quantum Computation, Quantum Information

SB041-018 TITLE: SpinnerBot

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: Develop a small, lightweight robotic device that incorporates a reel that pays out and retracts a supporting tether in a controlled manner and also includes additional forms of locomotion, sensors, and a communications and control processor. The purpose of this SpinnerBot with a tethered mobility scheme would be able to access complex interconnected spaces such as those within a collapsed building. The animal model for such mobility is a spider that can lower itself on a strand of silk, and spiders having this capability are termed “spinners.”

DESCRIPTION: Unmanned vehicles that employ tethers have generally done so out of necessity to provide required communications bandwidth and/or power not otherwise available to the platform. One example is undersea work vehicles with extremely high power requirements. The tensile strength of a physical tether can also be used to move or stabilize a vehicle. This has been done on an ad hoc basis to rescue and inspection robots incapacitated in harsh environments and is being explored as a deliberate strategy for a Mars planetary rover to explore otherwise inaccessible cliff faces. The tether should be more than strong enough to support the weight of the robot, so the robot could lift itself up. The tether should also bring power from the control unit (eliminating the need for heavy batteries) and provide a high bandwidth, bidirectional communications channel, so that the weight of on-board processing components can be minimized. The key technical elements of the SpinnerBot system are (1) the tether itself, combining tensile strength, small bending radius, power carrying capacity, and communications bandwidth; (2) the tether deployment subsystem, combining the tether actuators with sensors to measure tension in the tether as well as the length of tether paid out; (3) locomotion actuators such as wheels or legs; (4) sensors, such as cameras and/or microphones; (5) communications and control processing to manage the data communications process, format sensory data and execute commands to the actuators; and (6) the control unit, to provide the user interface, power, and communications interfaces to the tether. The system should be as small and lightweight as possible, while supporting a tether deployment of 30 meters and a sensor payload of three microphones and three small cameras with associated lights to provide 360-degree situational awareness.

PHASE I: Prepare a feasibility study for a SpinnerBot robotic device addressing all the key technical elements. Develop the tether mechanism for controlled reeling operations.

PHASE II: Design, fabricate, and integrate key technical elements of the SpinnerBot system. Demonstrate the tethered mobility scheme while accessing complex interconnected spaces using the SpinnerBot system.

PHASE III Dual Use Applications: The technology developed under this SBIR can be used in robotic exploration, urban search and rescue, battle damage assessment, inspection, and surveillance applications.

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KEYWORDS: Robots, Tethers, Spiders, Rappelling

SB041-019 TITLE: Cognitive Processing Hardware Elements

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace, Human Systems

OBJECTIVE: Identify critical cognitive processing architectural hardware elements and structures that will dramatically improve and enable the ability to perform cognitive information processing.

DESCRIPTION: The purpose of this SBIR topic is to identify and propose cognitive information processing structures and processing elements that will form hardware building blocks for efficient cognitive information processing.

Cognitive information processing algorithms are currently limited by existing commercial off-the-shelf (COTS) computing architectures. These architectures have been developed for numeric processing applications and numeric based algorithms. As a result, cognitive processing techniques are forced onto existing numeric processing structures and architectures. This is a mismatch of approach and hardware. At best this leads to inefficient implementations and results that do not represent the capabilities of cognitive information processing. Basic and underlying cognitive processing elements and structures that can form the architectural hardware building blocks for efficient cognitive processing implementations need to be identified, designed, and developed to enable efficient cognitive implementations and performance.

Today’s knowledge representations, abstraction (processing objects), architectures, and implementations are ad hoc, awkward and inefficient. Transformation from today’s cognitive techniques running on conventional computers is required to develop innovative DoD cognitive computing solutions. To realize the impact and promise of cognitive information processing approaches, basic hardware components and structures that support computing architectures attuned to cognitive processing fundamentals need to be established.

Representative cognitive processing examples need to be identified to serve as sources to examine cognitive processing structures. Future cognitive sensor processing systems may be comprised of conventional processing algorithms, knowledge based techniques, statistical techniques and dynamic learning techniques all integrated into a cohesive intelligent sensor system. High payoff potential candidate mission or applications are as follows: (1) unmanned combat air combat systems; (2) unattended ground sensors data fusion, and interpretation; and (3) dynamic (robust) computer resource management and fault tolerance. The primary and enabling processing architectural elements and structures can be examined and identified from these examples. The challenge is that today's architectures, applications, and software are defined in advance and locked during mission operation. Cognitive systems will not follow a predefined script or program. New system characteristics such as composable runtime, agile micro-architectures, fast irregular multi-dimensional memory system access, and interconnect-on-demand are required to efficiently support the emerging cognitive systems. The structures and architectural elements that can form a basis for efficient cognitive processing need to be analyzed and hardware implementations considered. Approaches to embed these cognitive elements within current processing structures to augment current capabilities need to be developed. These implementations need to be simulated and developed to demonstrate the potential to support efficient cognitive processing.

PHASE I: Identify and select high value DoD based cognitive information processing examples. Analyze these cognitive examples to identify processing elements and structures that uniquely enable or efficiently perform cognitive processing for these examples. Analyze current implementation approaches on existing COTS processing to evaluate and identify current limitations and the processing elements resulting in these limitations. Using identified structures and processing elements that support cognitive processing implementations establish the potential performance impact of the identified cognitive structures versus current COTS processing implementation. Using this analysis propose and design architectural hardware implementations that provide efficient cognitive processing structures.

PHASE II: Develop design implementations of the cognitive structures and elements established in Phase I. Develop the resulting architectural design approaches that enable efficient cognitive processing implementations. Develop representative designs as cognitive processing structures that can be embedded within existing processing design architectures or as new architectural implementations around which a cognitive architectural can be developed to enable efficient cognitive information processing. Through simulations evaluate the architectures and structures developed for cognitive processing and establish the performance improvements versus the baseline of cognitive processing performed on COTS numeric processors from Phase I.

PHASE III Dual Use Applications: The technology developed under this SBIR will be applicable across a broad set of DoD and commercial applications to implement cognitive processing approaches and enable or significantly improve the performance of intelligent systems. The processing elements, cognitive structure, and cognitive architectures developed will support intelligent battlefield information processing and decision making as well as commercial applications such as cognitively based medical diagnosis support and intelligent emergency and resource management to travel navigation.

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KEYWORDS: Cognitive Architectures, Cognitive Processing Structures, Cognitive Processing Elements, Cognitive Modules, Cognitive Processing Architectures, Cognitive Infrastructure, Intelligent Sensors.

SB041-020 TITLE: Knowledge Flow in Command and Control (C2)

TECHNOLOGY AREAS: Information Systems, Human Systems, Weapons

OBJECTIVE: Enable the design and development of an intelligent command and control (C2) operations center for the Joint Battlespace. Develop a comprehensive model of the information flow in a combined C2 environment for the targeting and analysis of information bottlenecks. Use a modeling and simulation approach to design and test strategies for mitigating bottlenecks in the C2 environment.

DESCRIPTION: A report from the Chief of Naval Operations Strategic Studies Group noted that the speed of command is compromised by fleet decision makers who are faced with too much data and not enough information. The problem of transforming data into actionable information is critical in the era of acre sized operations centers and sensor-rich net-centric warfare. To deal with this overload, a “smart” or intelligent operations center, would contribute significantly to force projection and the integration of multiple data sources for rapid command decisions. Ultimately an intelligent C2 center should have an implicit understanding of the people, functions, and temporal processes of the center and its mission. It should have awareness of "intelligent" tools and "dumb" objects and the context in which they are being used. An Intelligent C2 center should have a hypothesis as to what the operators are doing at a high level, and use this as the basis to interpret actions. To truly revolutionize C2, the center itself must be preemptive in thinking and decision making – it would interpret information and tell the user what it deduced, without waiting to be asked for particular information. This topic is targeting researchers working on the next generation of information processing for enhanced warfighter performance, in order to lay the groundwork for the revolutionary C2 systems of the future.

A substantial amount of research has been conducted on advanced information processing to support the individual operator within the C2 center. The Navy’s Tactical Decision Making Under Stress (TADMUS) and Multi-Modal Watch Station (MMWS) programs have invested in and significantly contributed to the design of Decision Support Systems that have demonstrated measurable improvements for the individual warfighter. These programs have shown that there is value in analysing information flow and identifying the bottlenecks that decrease human performance in these complex settings. This topic does not seek to duplicate the research already conducted – the goal is to leverage lessons learned and expand this type of analysis to the level of the entire operations center.

For this topic, the initial C2 environment explored should be a consolidated one, rather than distributed. The Air Force Combined Air Operations Center or the Navy’s Aegis Combat Information Center are centralized commands that present very difficult problem spaces. The first step in effectively improving information management in a combined C2 environment is to conduct knowledge engineering (reducing large bodies of knowledge to a set of facts and rules) to identify decision-making bottlenecks, impediments, and opportunities in the context of on-going military and non-military operations. This analysis should have a specific focus on identifying critical information exchanges between command centers at different echelons, and defining operational metrics for decision-making and speed of command in these contexts. The goal is to look at the operations center as a whole, not just one particular station or position. This analysis would then be used to identify the exchanges and opportunities for insertion of the most relevant information processing aids at the global level, creating the foundation for the intelligent C2 systems of the near future. This type of C2 environment would give our warfighters and decision makers an unparalleled advantage for battlefield management in upcoming conflicts. The net-centric focus of the joint battlespace mandates that we pay particular attention to the challenges of information flow and mitigate their effects before there is a critical breakdown. While the analysis would not be completely generalizable from specific environments, many fundamental lessons about information exchange and common bottlenecks could be gleaned from one particular application that could later be applied to other environments in further phases.

PHASE I: Phase I will be a study describing the dependencies and flow of information to and from people and information sources in a specific combined C2 center. The output of Phase I should be a complete analysis of all anticipated flows of information in this environment (i.e. call out specific information exchanges), as well as a static model/model plan of the entire flow (i.e. how all of the pieces fit together in the environment).

PHASE II: Phase II will have two components: 1) Produce a working model of the information flow in the C2 center. This model will then be used to predict and analyze where the bottlenecks, impediments and other challenges might occur in the C2 center. 2) Using the model as a guide, conduct an analysis using simulation tools to assess the current state of technologies that would aid information flow in the environment. Make recommendations based on this analysis, and use modeling and simulation to predict and test at least one potential improvement.

PHASE III: DUAL USE APPLICATIONS: The dual use applications for this analysis are significant with multiple DoD applications including urban warfare, high precision targeting, dynamic aircraft allocation, rapid replanning, and dynamic collaborative environments would all benefit from an improvement in C2 information flow. For commercial applications, any dynamic collaborative environment such as large scale control stations or nuclear reactor control rooms would benefit from this topic.

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KEYWORDS: Knowledge Engineering, Command and control, Decision-Making, Information Flow

SB041-021 TITLE: Building Battle-Space Models from the Bottom Up

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop rapid, efficient, and scalable methods for creating useful structured models of the battle-space by directly composing the domain knowledge from different military experts, eliminating need for top-down design and knowledge-engineering, and thus making it cheaper and faster to create structured content that computer algorithms can interpret.

DESCRIPTION: This topic seeks innovative approaches to creating structured content directly, rather than through the expensive and laborious conventional method of designing a representation top-down and populating it via knowledge-engineering. Enhancing our military command and control capability depends on automating many functions using smart algorithms, thus speeding situation awareness and improving decision-making. Automated command and control technologies such as artificial intelligence (AI) planning systems require structured data, defined as a set of variables whose values are constrained in some way and are associated with a particular contexts. Some of these variables are already available from databases, formatted messages, sensor feeds, and workflow applications. The key technical challenges are (1) to identify and develop approaches for encouraging the growth of structured content that represents the battle-space, and (2) develop incentives for end-users to create structured content, and (3) to find bottom-up methods of integrating the representation of these different sources of information by direct composition so that combining two or more of them has value for a particular military purpose. Previous approaches to creating battle-space representations more cheaply have included using knowledge-bases to expand a representation through deduction, creating knowledge-engineering tools suitable for end-users, and developing ontology tools to enable users to more easily declare semantics. This topic aims to create a battle-space representation through the direct composition of structured information which is or can be made easily available, rather than invented specifically for the purpose of the representation. Successful approaches will not depend on declared semantics, enable cheap and fast development of a structured model of the battle-space, and support arbitrarily large and more detailed extensions of this model to enhance coverage.

PHASE I: Conduct research and development to determine the scientific and commercial feasibility of creating a structured model of the battle-space bottom-up, through direct composition of available or easy-to-create digital content, as well as methods and tools useful for defining additional structured content.

PHASE II: Design, implement, test, and demonstrate a system for directly composing a structured model of the battle-space for selected domains. Compare the costs and utility of this approach with other methods. Identify significant limitations or advantages.

PHASE III Dual Use Applications: The technology developed under this SBIR topic can be used in many, many commercial business applications. The market is broad, and the opportunity is great: today, businesses handle nearly all analysis and decision-making manually. The dominant information systems today provide information that is not interpretable by algorithms, and therefore our computers cannot provide intelligent assistance. Research conducted under this topic will advance our ability to create and combine structured models that cover key information elements relevant to a problem-solving activity. Through composition, we'll be able to develop large models that will provide algorithms with enough context to support intelligent assistance. The utility of this technology is in no way limited to military applications.

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KEYWORDS: Structured Data Model, Representation, Ontology, Composition, Database, Battle-Space, Knowledge-Engineering

SB041-022 TITLE: Through-Wall Sensing (TWS) Technologies for Dismounted Infantry

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Human Systems

OBJECTIVE: Design and build a low-cost, light-weight, man-portable Through-Wall Sensing (TWS) device that is capable of detecting and tracking humans from outside a room or structure. The sensor should be suitable for use by dismounted infantry and be capable of detecting human activity through a variety of commonly used wall structures and materials with a low probability of false detections.

DESCRIPTION: Urban environments are increasingly sites of armed conflict. The Department of Defense is particularly concerned with the urban environment with respect to the safety of dismounted infantry who are called upon to fight in such environments. As a result, the Department is interested in providing technological solutions that dramatically enhance the ability of dismounted infantry to conduct military operations in urban terrain. One potential technology area is known as Through-Wall Sensing (TWS). A TWS sensor is a system that allows a user to sense the presence of an individual through an intervening door or wall using radio frequency sensing techniques. Several system variants have been developed to sense the location of a human subject inside of a room from the outside of that room.

A TWS system's ability to detect respiration gives it utility as a potential rescue system when it is used in the search for unconscious friendly, neutral, or enemy combatant subjects who may be injured. A TWS system can also be used to help military forces clear a building when people may be concealed in interior hiding places. At least one first generation product is available on the market for this purpose and there are a number of experimental systems that have been tested, all with varying results. All of the current systems must be operated from a fixed position secured to the intervening wall or mounted on a tripod. Under battlefield conditions, the requirement that a TWS sensor be positioned against the wall may place the human subject search team in danger.

To be fully useful to dismounted infantry (and potentially civilian emergency first responders: e.g., fire, police, & emergency medical), the sensor should have all-weather capabilities, be robust, rugged, light-weight, easily man-portable, and require little or no set-up time for only one person. It should require only the stabilization that can be provided by the soldier's unsupported stance and ideally should operate at a significant stand-off range from the structure or wall. The sensor should provide a display of the interior of the structure, identifying the location and motion of all human beings within the structure and mapping interior walls and inanimate obstacles.

Subject motion within the room may be generated by the subject moving while carrying out normal activities or the motion may be generated by the slight motion of the stationary subject's thorax during normal respiration. A TWS system's ability to detect the extremely slight motion associated with respiration is highly desirable. The ability to reliably detect the respiration motion ensures that a human cannot conceal their presence long term, given that the act of breathing is an involuntary response that cannot be suppressed over long periods of time. However, since the human thorax moves only a few millimeters during the respiration cycle, the ability of a TWS system to detect respiration associated motion requires that the system be extremely sensitive to motion. To achieve the required stability, the current generation TWS systems are stabilized as described above in order to eliminate motion artifacts that can mask the desired motion of the thorax. TWS self motion can be a source of false alarms.

Other potential useful capabilities of the sensor could include the ability to: (1) distinguish between vertical and prone subjects, (2) detect heartbeat or respiration, (3) detect booby traps, explosives or other obstacles within the room(s), and (4) detect the presence of weapons or explosives on subjects. To date, there have been some notable achievements using radar for TWS concepts; however, other sensors (infra-red, magnetic, acoustic, seismic, etc.) may also have distinct capabilities and advantages. Additionally, the possible integration of multiple sensors to achieve a superior TWS solution could be explored.

The objective of this topic is to demonstrate a practical TWS solution for dismounted infantry. Prospective developers should conduct a feasibility analysis of a specific solution. The analysis should conclusively demonstrate the capabilities of the proposed solution. A successful offering must include a preliminary discussion of the robustness and "user-friendliness" of the proposed device. Cost of the technology, must also be addressed.

PHASE I: Evaluate the feasibility of the technology using any combination of techniques such as analytical modeling and simulation, bread-board laboratory experiments, or preliminary field experiments using available hardware and software. The results should be sufficient to fully evaluate and analyze the performance and capabilities of the proposed solution. The research being solicited is for the design and demonstration of an RF-based TWS sensor and motion stabilization system that eliminates the need for the TWS being stabilized against the wall or placed on a fixed mount such as a tripod. The successful responder will propose at least two design approaches that can be used to allow the user of an RF-based TWS system to operate the system while it is hand-held without the TWS system losing the ability to detect the slight motion associated with respiration due to hand induced motion artifacts. Each proposed technique will be justified by presenting preliminary experimental data that each technique is viable. The successful respondent will design and demonstrate the best stabilization technique(s) during this phase. A major Phase I goal is to demonstrate that the enabling technology can be developed to accommodate a hand-motion stabilized TWS sensor that does not exceed $5,000 market price. Another second major Phase I goal is to demonstrate that the stabilization technique cancels the motion signature well enough to allow the respiration signatures of a human subject to be detected three meters behind a wall constructed of wall board or wooden door when the TWS sensor is operated 1 meter from the wall while being hand-held and directed at various locations on the wall.

PHASE II: If the respondent(s) is successful in demonstrating that the goals have been met during the Phase I effort, the respondent will design and build an RF-based TWS for hand-held operation utilizing the hand-motion cancellation system developed during the Phase I effort. The respondant will demonstrate the system's operation during a set of field experiments against a variety of live and inanimate targets in representative urban environments.

PHASE III DUAL USE APPLICATIONS: If successful, such through-wall sensing technology would have significant interest in both federal and local law enforcement communities for the use in high-stress situations such as sieges, kidnapping, hostage situations, and searches. Several other potential applications for effective TWS technology sensors include the high-stress environments encountered by fire and rescue personnel as well as Emergency Medical Technicians (EMT).

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KEYWORDS: Sensors, Through-Wall, Radar, Surveillance, Urban Warfare

SB041-023 TITLE: Physically-Small VHF SAR Antenna

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

International Traffic in Arms (ITAR) RESTRICTIONS APPLY:
Although this topic is unclassified, the results may have ITAR implications, i.e., might provide another country a technological or financial advantage over the United States. ONLY United States citizens and foreign nationals, who have been lawfully admitted for permanent residence in the United States under the Immigration and Naturalization Act, can participate in this SBIR effort.

OBJECTIVE: Develop antenna concepts and designs to provide very high frequency (VHF) synthetic aperture radar (SAR) capability on medium-sized unmanned aerial vehicles (UAVs (e.g. Predator, A-160 Hummingbird) and/or for roll-on / roll-off applications.

DESCRIPTION: VHF-band (e.g. 20 – 90 MHz) foliage penetration synthetic aperture radar (FOPEN SAR) has demonstrated the ability to reliably detect targets under dense tree stands. Achieving the maximum tactical value and flexibility with VHF SAR may mandate its installation on tactical-sized UAVs such as the Air Force's Predator and the Army's A-160 Hummingbird (offerors are encouraged to consult standard references as a guide to UAV parameters), or possibly as a roll-on system to a platform such as an A-130 gunship. This presents a technical challenge in achieving adequate antenna characteristics (gain, impedance match, backlobes, sidelobes, etc.) within the allowable size, weight and mechanical constraints.

Specific design considerations requiring particular attention for a VHF SAR include: 1) control of the antenna backlobes to minimize image artifacts, 2) control of the elevation pattern to minimize susceptibility to RFI, 3) impedance matching over the entire band and 4) control of azimuth sidelobes. The desired frequency band is approximately 20 MHz to 90 MHz, however it is not mandatory that this band be covered instantaneously. Currently-contemplated radar designs include both linear FM-ramp and stepped-frequency concepts. Consideration will be given to antennas that incorporate active tuning synchronous with the waveform frequency. A single polarization design (e.g. horizontal) is ac-ceptable; however antenna concepts providing dual orthogonal polarizations will receive particular interest.

PHASE I: Develop and model antenna concepts that show merit in meeting UAV and roll-on / roll-off constraints, and that address the requirements of a VHF SAR.

PHASE II: Develop detailed electromagnetic models of the selected antenna design. Demonstrate ability of the selected design to operate within airframe and operational constraints, and to achieve acceptable voltage standing wave ratio (VSWR) over the entire band.

PHASE III Dual Use Applications: Antenna concepts and designs can be applied to existing future Army and Air Force FOPEN SAR systems. In addition commercially-operated VHF FOPEN SARs could use these antennas to perform Interferometric SAR (IFSAR) or stereo SAR mapping, allowing the generation of accurate digital elevation models (DEMs) of terrain under foliage.

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KEYWORDS: Foliage Penetration (FOPEN) SAR, Airborne Antennas, Frequency-Tuned Antennas, Wideband Antennas, VHF Radar

SB041-024 TITLE: Group Tracking Techniques for Foliage Penetration Ground Moving Target Indication Radars

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

International Traffic in Arms (ITAR) RESTRICTIONS APPLY
Although this topic is unclassified, the results may have ITAR implications, i.e., might provide another country a technological or financial advantage over the United States. ONLY United States citizens and foreign nationals, who have been lawfully admitted for permanent residence in the United States under the Immigration and Naturalization Act, can participate in this SBIR effort.

OBJECTIVE: Develop techniques to enhance foliage penetration (FOPEN) Ground Moving Target Indication (GMTI) radar tracking of group targets (e.g. squads of dismounted troops).

DESCRIPTION: GMTI radar trackers are being developed to track vehicle targets. Such targets generally tend to move for considerable distances over constrained routes (e.g. road networks). A foliage penetration GMTI radar would add a unique dimension to the target tracking problem, as it would operate at P-band (i.e. 420 – 450 MHz), have range resolutions of nominally 5 – 10 m, and azimuth beamwidths of 5 – 10 degrees.

Tracking groups of individuals through foliage with a P-band radar is a very challenging task, especially when the group is small and can be dispersed over an area of several thousand square meters. Among the unique problems that must be addressed are: 1) the separation of the troops, 2) the low, differing and continually varying target speeds, 3) the fact that the group does not behave as a rigid body, and 4) the intermittent loss of signal detections due to target obscuration, foliage attenuation and/or radial velocities below the minimum discernable velocity (MDV) of the radar. In addition, the group may not have any net forward velocity, but instead be performing activities in a fixed locale.

Addressing this tracking challenge will require operation of the FOPEN GMTI radar from a nominally stationary, high-altitude platform such a helicopter or low-speed unmanned aerial vehicle (UAV) to provide persistent surveillance and a low detectable target velocity. Multiple radars acting in concert may also be required. Any tracking system used by these radars will require unique processing algorithms that can exploit the relatively long time required for groups of people to traverse a significant distance (especially under foliage). The algorithms might use topographic databases and track history data to predict line-of-sight visibility, probable routes and speeds, clear and foliated areas, etc. The algorithms must contend with low signal-to-interference ratios, modest radar range resolution and coarse (e.g. 5 to 10 manipulative radar deception (mrad)) angular accuracies at distances of 15 - 30 kms, although target revisit rates could be as frequent as every 5 seconds to enhance performance.

PHASE I: Develop and assess algorithms for performing the detection and tracking of group targets that could be used in a FOPEN GMTI radar.

PHASE II: Implement the algorithms developed during Phase 1 on a PC or workstation. Demonstrate performance using Government-furnished GMTI radar data.

PHASE III Dual Use Applications: The algorithms developed under this effort would be applicable to both military FOPEN GMTI radars and to commercial security / homeland defense systems that use active surveillance sensors to protect large areas such as industrial complexes and airports where an attack by a terrorist group is a viable threat.

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KEYWORDS: Tracking, GMTI Radar, Foliage Penetration Radar, Group Detection

SB041-025 TITLE: <u>Low-Cost, Low-Power Radar For Small Unmanned Aerial Vehicles</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

ITAR RESTRICTIONS APPLY

OBJECTIVE: Develop low-cost, low-power radars to provide all-weather, 24/7 stand-in surveillance capabilities for small units of action.

DESCRIPTION: Interest in small unmanned aerial vehicles (UAVs) supporting stand-in surveillance and reconnaissance has grown exponentially in recent years, and is due, in part, to significant improvements in micro-electronics, the commercialization of global positioning system (GPS) navigation, the development of affordable wireless communications technologies, and the refinement and proliferation of micro-mechanical systems (MEMS). Sensor development for small UAVs has favored passive optical systems because of their low power consumption, low cost, and the ease of interpretation of the resulting data products. Unfortunately optical systems require good weather and passive systems are only effective during daylight hours. In addition, current passive and active optical systems are not effective operating through foliage and are susceptible to obscurants such as smoke. Finally, the search rates for optical systems tend to be relatively low; suggesting that they are most effective when coupled to other (cueing) systems.

Representative UAVs (and familiar to the author) include the Drag Eye, Silver Fox, Seascan, and Aerosonde. Information on these and similarly sized UAVs relevant to this solicitation can be found on the World Wide Web. A couple of references are included below (Ref. 1. and 2.). Available SWaP (Size, Weight, and Power) for the payload varies with the platform. Typical weights range from 1 to 10 lbs, and power from a few to maybe 100 watts. Radars have been fielded within the SWaP constraints of these UAVs, although for other applications (e.g. Ref 3. and 4.). High bandwidth communications supporting air-to-ground and air-to-air communications, such as 802.11b, should fit within the constraints of numerous smaller UAVs.

Radars offer the potential for effective surveillance in virtually all weather conditions 24 hours a day. Properly designed systems can provide high update rates on relatively wide fields of regard. Resolution and hence interpretability is typically traded against other performance metrics such as search rate, processor throughput, required communications bandwidth, etc. Unfortunately, until recently, radar technologies did not scale well to small UAVs, which severely restrict payload size. With the advent of high performance digital processors, field programmable gate-arrays (FPGAs), and radio frequency (RF) and baseband analog electronics, not only can low-cost, low-power radars (LCLPRs) be built, they can be fielded with low capital investment by the developer and low cost can be achieved from small production quantities.

Some military applications for LCLPRs hosted on small UAVs include detection, localization and imaging of stationary and moving targets in the clear and in foliage, characterization of local terrain, and cueing for higher resolution systems such as optical cameras and laser radars. Targets of interest typically include military and commercial vehicles and dismounts (humans) and related supplies. Military vehicles are often typified as having radar cross-sections (RCS) of approximately 10dBsm (although smaller scatterers are of interest in higher-resolution implementations) while humans can have RCS of 0dBsm or less (Ref 5.). In clutter-limited applications these cross-sections are further reduced by the two-way attenuation of foliage when operating in a foliated environment (Ref 6). Commercial applications for the technology might include terrain characterization, surveying of buried service lines (e.g. electricity, gas, and water) and may facilitate search-and-rescue operations relevant to homeland defense applications.

The small (capital) barrier to entry and the multitude of applications, and hence design concept approaches, make this area of development well suited to the small-business innovative research program. Because of the potential military applications, development of these radar systems may be governed by ITAR regulations.

PHASE I: Identify potential applications and develop system concepts for candidate radar system(s) to detect militarily significant targets at ranges exceeding 1km. System should consider not only the radar hardware configuration but should also identify candidate host small UAVs and their associated constraints on radar size, weight and power. Consideration should also be given to radar control, motion compensation and the egress of data from the platform for exploitation locally. Existing, high-production / low-cost electronics should be considered for use where possible. The sensor design should consider electromagnetic compatibility both as a source and potential recipient of electromagnetic interference (EMI) and the ability to operate effectively in a stand-in surveillance environment. Ideas to operate multiple UAV-based radars concurrently to achieve a desired result are encouraged. Phase I should include the completion of a detailed plan to develop and demonstrate a radar on a small UAV in Phase II. Projected costs for larger-scale production of the radar should be included as part of this effort.

PHASE II: Design, fabricate and test radar on a small UAV demonstrating, through implementation, the fielding of a LCLPR for use in stand-in surveillance applications.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used for local terrain characterization, surveying of surface and sub-surface structures (ref. 3) and possibly search-and-rescue operations.

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KEYWORDS: UAV, Radar, FOPEN, GPEN, DTED

SB041-026 TITLE: Innovative Hypothesis Management

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop innovative approaches to Multiple Hypothesis Tracking (MHT) that provide improved ambiguity resolution capabilities and therefore enhanced Long Term Track Maintenance (LTTM).

DESCRIPTION: While MHT approaches have grown in application and features since their introduction in the 1970s, the basic underlying hypothesis management has remained effectively unchanged. MHT algorithms address computational issues by pruning least likely hypotheses and current adaptive hypothesis pruning methods driven by variable tree depth and/or breadth parameters still have difficulty providing LTTM. This is especially true in dense target environments even with high sensor revisit rate operations. Signature features from High Range Resolution (HRR) modes, for example, can mitigate track ID ambiguity but may require long (relative to hypothesis tree depth) time intervals because of their availability and aspect dependence. Therefore the relevant ambiguity information may be lost before the signature features can be utilized. Additional information, including a priori and Level 2/3 Fusion feedback, that should also be considered, can greatly increase the complexity and correlation of any hypothesis space, thereby also complicating any management approach. Approaches developed under this effort should efficiently manage the expanded hypothesis space formed by the combination of kinematics, feature, domain, and other information present in current and future surveillance systems.

PHASE I: Perform an initial assessment and design of an innovative hypothesis management approach to multi-object tracking. Perform analysis and limited implementation to validate the design approach.

PHASE II: Expand the concept developed under Phase I. Develop a functional tracking prototype and demonstrate performance in a variety of scenarios.

PHASE III Dual Use Applications: The technology developed in this topic is also applicable to commercial surveillance systems used for physical security and law enforcement.

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KEYWORDS: Sensors, Simulation, Battlefield Models

SB041-027 TITLE: Flat Head-Mounted Displays

TECHNOLOGY AREAS: Sensors, Human Systems

OBJECTIVE: The goal of this program is to develop and demonstrate flat head-mounted display concepts that eliminate auxiliary optical systems (lenses, prisms etc). These displays will be extremely compact and simple and will work without interfering with the natural scene vision.

DESCRIPTION: Modern warfare is becoming increasingly information-centric. Rapid advancement in the ability to gather information (via multitudes of sensors), process it and share it among many potential users has impacted platform designs in a fundamental way. Except in the case of an autonomous system, a human being is the ultimate consumer of this information. Display of information has therefore become a critical aspect of system design. Progress in various display technologies (liquid crystal, plasma, organic light emitting diode (LEDs)) has led to displays that are increasingly compact and light. Standard desk top displays are viewed by a human operator from a distance where no intervening optics is needed; hence the decreasing size and form factor of the displays translates directly into reduced system size. This is not the case with head mounted displays. The distance between the display itself and the human eye is typically of the order of 5-10 cms hence intervening optics is needed. As a result, the reduction in the displays themselves does not lead to a compact display system. The depth (or thickness) of a display is usually comparable to its linear size and often exceeds it significantly. This limitation makes the head mounted displays bulky and often heavy. Furthermore, this size and weight limitation is fundamentally due to the use of auxiliary optics and hence will not be overcome through advances in display technology.

In many cases, sensor or computer generated information needs to be superposed on a naturally viewed scene. This implies that the displays themselves should minimally obstruct or distort the view. Again, this capability can be obtained in the existing head mounted displays by using a beam combiner in front of the eye(s) while the displays are mounted on the helmet and imaged by a relay lens system.

The goal of this program is to achieve a 10x reduction in system thickness (and therefore volume) of the head mounted display. If an external illumination is needed, its volume and weight should be minimized and it should be preferably deployed away from the helmet.

In this program, we want to encourage researchers to develop alternate representations of information that are amenable to decoding by human visual system. Factors to be investigated are:
Computational complexity of the encoding algorithms
Requirements on display devices for representing the coded information
Level of visual artifacts produced
Amount of distortion introduced in natural scenes.
The complexity of information that can be displayed using the suggested approach.

PHASE I: Investigate new representation of information and associated computer coding required for a head-mounted flat display system. Demonstrate feasibility for non-real time (fixed) information display. Identify display technology specifications for a real-time display.

PHASE II: Demonstrate head-mounted, flat display for real-time updatable information. Demonstrate computer generated discrete, alpha-numeric data and other iconic information. Perform study using the same approach to display continuous image information acquired by non-visible image sensors.

PHASE III DUAL USE APPLICATIONS: Head mounted displays have extremely broad applications in the commercial world ranging from electronic games industry to the maintenance and repair of complex machinery and medicine. Military applications correspond to helmet mounted vision system that combines images obtained in several different wavelengths and displays them in a natural manner to the warfighter. Similarly presenting computer generated symbolic information on a compact helmet mounted display without affecting the normal vision would be valuable to pilots of fixed wing and rotary wing aircrafts.

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2. Optical assessment of head-mounted displays in visual space. Applied Optics v. 41 no25 (Sept. 1 2002) p. 5282-9.

KEYWORDS: Head-Mounted Displays, Liquid Crystal, Image Transforms

SB041-028 TITLE: Large Asset Sensor/Actuator Networks

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes, Sensors, Electronics, Battlespace, Space Platforms

OBJECTIVE: Develop a process to seamlessly integrate circuitry or backplanes of sensors and/or actuator networks into structural materials of large-area, high-value military assets (buildings, vehicles, etc) through the basic building materials of composite beams, panels, or tiles.

DESCRIPTION: The largest and highest value assets in the military (besides people) are buildings and weapon systems platforms. These assets typically have large areas that can be exploited by incorporating electronic sensing and actuation to gain information concerning the assets itself as well as its operating environment. By incorporating microelectronics (MEMS), and/or electro-optics, available area that is typically used for structural integrity can be exploited (with negligible physical or mechanical effect to the structure itself) to achieve a large area distributed network. The incorporation of a distributed sensor/actuator network in these applications will require significantly large numbers active components and the means to robustly connect them. The incorporation of sensors/actuators and automatic interconnection during the manufacturing process can be achieved with minimal cost, performance tradeoff, and obtrusiveness. It will provide a “nervous system” to the building or vehicle and thus allow the ability to achieve total awareness of internal and environmental stimuli and the ability to dynamically react to changes. Fibrous matrices of composites can serve a dual purpose of load distribution as well as information distribution and real time reaction to external stimuli. Use of conductive polymers, fiber optics, fiber sensors, and composites allow both active and passive components to be incorporated into form factors with high aspect ratios. The current effort would seek methods of incorporating the basic modular sensor/actuator network in the fundamental materials and interconnected during construction. Incorporating a large area sensor network into large military assets could enable a variety of applications including: warning signs of potential threats, dynamic sensing of structural integrity or surface irregularities, real-time corrective actions through actuated materials, sensing for condition based maintenance.

PHASE I: The focus of Phase I will be to devise a cost effective method of integrating the essential elements of the sensor/actuator network into building materials with minimal performance and weight trade-off. The objective of this phase is to examine alternative methods of incorporating electronic components to the most basic and scaleable component of the building material and methods to electrically interconnect those components during construction of the vehicle/structure itself. The Phase I deliverable will be a scaleable circuit design, mechanical model of the resultant building material, a technical description of construction/interconnection schemes, and a plan describing how the networked material will be fabricated and tested.

PHASE II: The focus of Phase II will be to fabricate a functional tile/beam/panel based upon the design completed in Phase I. The material will be tested in accordance with the Phase I test plan to determine electrical and mechanical integrity and circuit performance.

PHASE III Dual Use Applications: Candidate applications for large asset sensor/actuator networks lie in the domain where large area and conformability are of greater importance than high-speed performance or packaging density. Applications of this technology are in automobiles, ships, buildings, intelligent living spaces, etc.

KEYWORDS: Composite, Fiber Optics, Chemical-Bio Sensors, Actuators, Matrix, Conductive Polymer

SB041-029 TITLE: Computational Framework for Mixed Electromagnetic and Electrical Circuit Simulation

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Space Platforms

OBJECTIVE: Develop and demonstrate a generalized computational framework for problem definition and diagnosis that has the flexibility to quickly and efficiently simulate electromagnetic (EM) effects coupled to electrical circuit simulations with application to the computer aided design (CAD) of advanced mixed-signal systems.

DESCRIPTION: In order to meet the challenges in advanced mixed-signal simulation and design, it is necessary to develop CAD tools to identify and correct problems early in the design process. However, design and optimization of this complex electromagnetic environment is slow, expensive, and error prone. A variety of electromagnetic modeling methods must be applied to a single problem in a self-consistent manner in order to accurately and efficiently predict the required electromagnetic interactions and couple these interactions to a circuit simulation. A wide variety of Computational Electromagnetic (CEM) tools currently exist for electromagnetic analysis, each tied to a particular design philosophy and modeling methodology. These tools typically have different problem definition and diagnostic requirements. By approaching the development of problem definition and diagnostic requirements from an object abstraction viewpoint, a framework can be built that allows new capabilities, as well as new accurate modeling techniques, to be quickly addressed by the framework. DARPA is interested in exploring whether a properly designed object abstraction framework can be developed that demonstrates a high degree of flexibility and low maintenance costs.

The framework must be able to perform diagnostics for and interface to solution tools that employ hybridization of various techniques such as finite elements with boundary elements (both geometry and numeric), efficiently couple to circuit simulation and lend itself to optimization of design parameters.

PHASE I: Develop new concepts, models and numerical methods to accurately and efficiently represent the interface between electromagnetic analysis and circuit simulation for high speed (>10 GHz) mixed signal circuits. Develop a design for an advanced object abstraction framework for the interface to enable automated analysis of coupled electromagnetic and electrical circuit phenomena. Perform preliminary evaluation of the interface and the framework using existing public domain (or commercial) electromagnetic and circuit simulators.

PHASE II: Develop the computational framework to accommodate mixed methodologies (differential as well as integral formulations) for treating the EM domain in an automated manner. Implement automatic adaptive meshing for improved computational accuracy. Develop appropriate model order reduction (MOR) techniques to resolve EM interactions in circuit simulators. Demonstrate tools for the design of a high performance, mixed signal system of relevance to the military. Quantify performance of tools.

PHASE III Dual Use Applications: This effort will provide an important foundation for the acceleration of improvements in the CAD for advanced mixed-signal circuits. Electromagnetic interference in electronic circuits is becoming a difficult problem to overcome as circuits scale into the deep sub-micron regime and operate at higher and higher speeds. The tools developed in this research will enable the consideration of these effects in the design process thus resulting in more robust circuits.

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KEYWORDS: Computer-Aided Design, Mixed-Signal Circuits, Computational Electromagnetics, Circuit Simulation

SB041-030 TITLE: Lithography Support Technologies

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop new tools to enhance performance and yields in the lithography processes in fabrication of semiconductor device with features below 100 nm. Performance improvements include control of feature sizes, pattern fidelity, overlay between levels, reduced line-edge roughness, and image placement. Yield improvement includes defect identification and repair, cleaning, and the controls cited above.

DESCRIPTION: The continuing increase in performance in microelectronics is made possible by the steadily decreasing size of transistors, summarized in the popular press as Moore's law. The key contributor to this improvement has been the lithography process which defines the intricate structures of the silicon chip. Conventional manufacturing problems are exacerbated as optical lithography pushes to sub-wavelength exposures for features below 100 nm. These problems range throughout the entire lithography process, including such as metrology, inspection, mask repair, cleaning, and stage control. The emerging nanoimprint technology introduces even more stringent demands on template preparation for imprint.

PHASE I: Evaluate the approach to address one of the above problem areas, providing overall system architecture and detailing a path to solution of key challenges. Explore alternative approaches for critical areas.

PHASE II: Evaluate the approach to address one of the above problem areas, providing overall system architecture and detailing a path to solution of key challenges. Explore alternative approaches for critical areas. Begin hardware implementation and initial verification for major subsystems.

PHASE III DUAL USE APPLICATIONS: The technology developed will apply to integrated circuit designs for military systems Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR), as well as commercial markets for application specific integrated circuits (ASICs) and high volume memory and microprocessor applications.

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KEYWORDS: Lithography, Metrology, Inspection, Mask Repair, Imprint

SB041-031 TITLE: Monolithic Integration of Photonic and Electronic Devices for High Performance EPICs (Electronic-Photonic Integrated Circuits)

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop low cost high performance integrated circuit technology platforms combining multiple electronic and photonic components for optical systems applications.

DESCRIPTION: Many modern military platforms require increased data access, high speed communications and processing ability. While optics provides the channel bandwidth required, advanced, low-cost and multifunctional photonic component technology has lagged behind in taking advantage of this capability. For example, there has been considerable progress in demonstrating very high performance optoelectronic integrated circuits (OEICs), particularly in the domain of receivers typically combining a single optical detector with a complex multi-transistor based preamp[1]. Additionally, photonic integrated circuits (PICs) consisting of multiple photonic functions (e.g. detection, light generation, and light guiding) have also seen both laboratory and commercial success[2]. Yet, a significant problem remains in combining transistor technology with PICs containing multiple photonic components that are designed to address a particular system need. Based on present PIC integration platforms, this SBIR topic aims to lead to the demonstration of practical methods for integrating both high performance transistors (for example, high electron mobility or heterojunction bipolar transistors) with a photonic integrated circuit to improve overall component performance. Example EPICs (Electronic-Photonic Integrated Circuits) might include a laser/modulator chip integrated with a high electron mobility or bipolar transistor linearizing modulator driver circuit along with a laser current stabilization and temperature sensing circuit. An alternative example is the integration of feedback electronics with a wavelength sensitive optical element to effect wavelength control of an integrated tunable laser. These combined OEIC/PIC components should eventually lead to the realization of a new generation of low cost, light weight, and low power multifunctional, self-contained monolithic integrated components for ultrahigh bandwidth, wavelength and time domain multiplexed optoelectronic device capabilities.

PHASE I: Demonstrate feasibility of a simple, low cost and manufacturability integration scheme for the monolithic integration of transistors and photonic and optoelectronic devices such as a lasers, receivers, modulators, and passive components. The 1.3 or 1.55ƒÝm wavelength OEPIC demonstration device must be motivated by a significant applications need in modern photonic systems. The scheme should minimize material growth and fabrication steps.

PHASE II: Demonstrate a functional OEPIC satisfying an important system need, and consisting of more than one electronic and photonic component. The component must be manufacturability at low cost due to its design simplicity and adaptability to standard (computer aided design) CAD tools. The component must be chosen based on its ability to significantly enhance performance over that obtainable with hybrid circuit combinations.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in high-end commercial wavelength division multiplexing (WDM) and all-optical network applications where data bandwidths of >10Gb/s/channel are common. Also, components including integrated laser/modulator chips with linearizing RF modulator driver electronics can be used in many DoD RF analog systems such as in phased array antennas used on airborne and ship-borne platforms where cost, weight and power consumption must all be minimized.

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KEYWORDS: Photonic/Electronic Integration, Fiber-Optics, Integration, Photonic Integrated Circuit, Optoelectronic Integrated Circuit

SB041-032 TITLE: Thermal Management Technology for High Average Power Solid State Lasers

TECHNOLOGY AREAS: Sensors, Weapons

OBJECTIVE: Develop components for lighter weight, smaller volume thermal management systems used for acquiring the heat from diode pumps and the laser gain medium for medium and high average power solid-state lasers and rejecting this heat to a heat sink.

DESCRIPTION: Medium to high average power solid state lasers (10 – 100 kW) have great potential for use in warfighting, however their low efficiency leads to considerable heat generation that must be acquired and then rejected to a heat sink that is not a part of the laser system. The weight and volume of the hardware for this thermal management system exceeds that of the laser by more than a factor of ten. This can entirely preclude the use of such laser systems in a battlefield environment. For example, a 100kW laser that is 12% efficient may produce about 700kW of waste heat that must be transferred to the atmosphere or some other heat sink. The size of the cooling system might be 1,400 cubic feet and weigh 10,000 kg, whereas that for the laser is 70 cubic feet and weighs 1,000 kg. Thus an advanced thermal management approach is needed for both heat acquisition (and heat rejection) that will result in a much smaller and lower weight system. Further, uniform removal of heat from diode bars being used to pump the laser medium is a special challenge as the actual temperature of the diode bars must be kept uniform to within plus or minus 2 degrees Centigrade over the diode cooling area of 100 square centimeters. To achieve this degree of control over diode temperatures over this large an area, considerable innovation is needed. One approach is phase-change cooling. Significant challenges exist in heat rejection as miniature high performance compressors, motors, and pumps are also needed.

PHASE I: Prepare a feasibility study for producing advanced heat acquisition and heat rejection components that, for a laser having 100kW of output power, could lead to the following performance for every 1 kW of heat removed from the laser: 0.2kW of electrical power supplied to the cooling system, 5kg of cooling system mass, and 0.01m3 of cooling system volume.

PHASE II: Design and fabricate a closed cycle diode cooling component technology that, compared to a micro-channel diode cooling system, would require 10x less coolant flow, weigh 10kg/kW of heat removed from the laser, and occupy a volume of 0.03m3/kW of heat removed from the laser. Demonstrate this cooling technology by removing a heat flux of 500W/cm2 from a surface area of 6 cm2 (2cm x 3cm) with a temperature uniformity of the diode interface surface of plus or minus two degrees Centigrade.

PHASE III DUAL USE APPLICATIONS: The technology for this can be used for cooling efficient high power solid state lasers for materials processing in the transportation industries.

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KEYWORDS: Phase Change Cooling, Microchannel Coolers, Diode Laser Cooling