DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
SBIR 2006.2 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. In accordance with Executive Order 13329, DARPA is also pursuing manufacturing-related R&D through manufacturing processes, equipment and systems protection.

DARPA has identified technical topics to which small businesses may respond in the second fiscal year (FY) 2006 solicitation (FY 2006.2). 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 requires electronic submission of Cover Sheets, Technical and Cost proposals, and Company Commercialization Reports. Only proposals submitted through the on-line submission site at www.dodsbir.net/submission will be processed or considered for award. Proposals must be prepared and submitted in accordance with the DoD Program Solicitation at www.dodsbir.net/solicitation and the following instructions below.

PLEASE DO NOT ENCRYPT OR PASSWORD PROTECT YOUR TECHNICAL PROPOSAL

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**.

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 II 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 1-888-227-2423 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 will process 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.

DARPA FY2006.2 Phase I SBIR
Checklist

Page Numbering

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

Proposal Format

b. Cover Sheet, Technical and Cost proposals, and Company Commercialization Report MUST be submitted electronically ______

c. Identification and Significance of Problem or Opportunity ______

d. Phase I Technical Objectives ______

e. Phase I Work Plan ______

f. Related Work ______

g. Relationship with Future Research and/or Development ______

h. Commercialization Strategy ______

i. Key Personnel, Resumes ______

j. Facilities/Equipment ______

k. Consultants ______

l. Prior, Current, or Pending Support ______

m. Cost Proposal ______

n. Company Commercialization ______

SUBJECT/WORD INDEX TO THE DARPA FY2006.2 TOPICS

Subject/Keyword Topic Number

DARPA SBIR 06.2 Topic Index

SB062-001	Nanofluidic Based Sensors for Chemical and Biological Agent Detection
SB062-002	Source Technology for Terahertz (THz) Hyperspectral Spectroscopy, Imaging, and Communication
SB062-003	High Temperature Corrosion Resistant Nanocomposite Materials for Turbine Engine Applications
SB062-004	High-Intensity, Narrow Emission FRET Probes for Single-Molecule Spectroscopy
SB062-005	Portable Oxygen Generator
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SB062-007	Extremely Low Attention Demand Information Systems (ELADIS)
SB062-008	Distributed Cooperative Human Agent Problem Solving
SB062-009	Specialized Robot / Human Teams for Limited Tactical Maneuvers
SB062-010	Anomaly Detection
SB062-011	Moving Target Detection, Classification and Identification in Urban Warfare Environments
SB062-012	Computer-Assisted Negotiation for Distributed Logistics
SB062-013	Kilowatt-Class, Chip-Scale, Laser Diode Phased Arrays
SB062-014	Optical Modulator Bias Control for Analog Fiber Optic Link Applications
SB062-015	Silicon-Based Infrared Imaging Sensor
SB062-016	Electro-Optic Polymer Based Ultra-Linear Directional Coupler
SB062-017	Integration of Ultra-High-Q Microresonators with MEMS for Tunable Coupling
SB062-018	Multi-Sensor Weapons Detection
SB062-019	Chemically-Driven Light Sources
SB062-020	Sparse Array Applications for Small Satellites
SB062-021	Multiple Foveated Vision Sensor for Bandwidth Optimization
SB062-022	Low Cost Distributed Explosive Detection Device
SB062-023	3D Visualization for Serpentine Robotic Systems

DARPA SBIR 06.2 Topic Descriptions

SB062-001 TITLE: Nanofluidic Based Sensors for Chemical and Biological Agent Detection

TECHNOLOGY AREAS: Air Platform, Chemical/Bio Defense, Ground/Sea Vehicles, Biomedical, Sensors

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

OBJECTIVE: The objective of this topic is to develop innovative nanofluidic based technologies for incorporation into a compact, portable sensor platform for use in the detection and identification of chemical and/or biological agents.

DESCRIPTION: A large body of work exists on the use of microfluidic-based systems for chemical and biochemical analysis, in fact, microfluidic technologies have advanced to the point that there are several commercial laboratory systems that can do chemical sensing, processing, and analysis. An area of emerging research that needs further development is the use of nanoscale fluidic channels and associated components to allow chemical and biochemical processing on the molecular level, such as molecular sorting and sieving to increase concentrations of analytes, or to trap single molecules for analysis. The ability to reliably fabricate nanofluidic-based devices may prove to be the enabling technology necessary for the production of a new class of compact, highly sensitive chemical/bio sensors.

The technology developed under this topic should be applicable to a wide range of chemical/bio sensors including the detection of chemical warfare agents, biological warfare agents, and toxic industrial materials and chemicals. Any proposed nanofluidic-based sensor should be designed with the following considerations in mind: 1) low power consumption operation, 2) capability for remote operation, including wireless data transmission, and 3) ruggedized construction for use in battlefield scenarios such as mounted on unmanned aerial vehicles (UAV's) and/or unmanned ground vehicles (UGV's).

In support of this effort, selective U.S. Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) fabrication and testing facilities are available for use by SBIR contractors AT NO CHARGE. Specific government furnished equipment (GFE) and restrictions are available upon request.

PHASE I: Conduct a feasibility study on the design and development of a nanofluidic based chemical/bio sensor. Concepts addressed during this phase should include the fabrication of nanoscale fluidic channels and other critical device components.

PHASE II: Develop a prototype chemical/bio sensor system from the Phase I effort. Experimentally test and validate the performance of the prototype system. Submit a working prototype to the Army for testing. Phase II and beyond are subject to ITAR restrictions.

PHASE III DUAL USE APPLICATIONS: The sensor platform technologies developed under this topic will have broad dual use applications outside of the military area of battlefield chemical/bio agent detection. Other areas of potential use are detection and early warning systems for homeland defense applications, systems for monitoring environmental quality (e.g. farm chemical run-off), and in industrial chemical manufacturing applications such as monitoring air and water quality for the release of toxic chemicals.

REFERENCES:
1. Proceedings of SPIE, Volume 5718, Microfluidics, BioMEMS, and Medical Microsystems III
Ian Papautsky, Isabelle Chartier, Editors, January 2005.
2. A. Bange, D. Wong, C. Seliskar, H. Halsal and W. Heineman. Microscale Immunosensors for Biological Agents. Proc. SPIE 2005; 5718:142-150.
3. Kuo, T.-C., D.M. Cannon, Jr., M.A. Shannon, P.W. Bohn, and J.V. Sweedler, "Hybrid Three-

Dimensional Nanofluidic/Microfluidic Devices Using Molecular Gates," Sensors and Actuators A: Physical, vol. 102, no.3, pp. 223-233, 2003.

KEYWORDS: Nanofluidics, Microfluidics, Chemical/Bio Sensor.

SB062-002 TITLE: <u>Source Technology for Terahertz (THz) Hyperspectral Spectroscopy, Imaging, and Communication</u>

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

OBJECTIVE: Develop a powerful, tunable, compact, frequency stabilized THz source

DESCRIPTION: Our ability to operate in the 0.1 – 1.0 terahertz (THz) region of the electromagnetic spectrum has increased dramatically in the last decade owing to the development of improved source technologies, including compact backward wave oscillators, high pressure optically pumped far infrared lasers, tabletop THz free electron lasers, IMPact Avalance Transit Time (IMPATT) diodes, and photoconductive switches excited by tunable Ti:Sapphire lasers. However, the frequency stability of these sources still requires improvement because of the difficulty of referencing or locking them to external reference frequencies or cavities. The DoD is interested in the demonstration of a rapid scan, single frequency (spectral purity << 1 MHz), low noise (rms < 0.01%), compact (< 1 cubic meter) THz source that may be adapted to a variety of applications. Of particular interest are source technologies which operate in both swept and single frequency mode with significant power delivery (> 1 microwatt) at frequencies continuously tunable throughout the 0.1 - 1.0 THz region that can be reliably and simply frequency locked to an external frequency standard or cavity. The source may subsequently be amplitude, frequency, or phase modulated for communication applications or may be coupled to an imaging spectrometer that can rapidly (< 10 minutes) sample a wide (> 0.1 THz) spectral region with variable spectral (< 1 MHz to > 0.01 THz) and spatial resolution.

PHASE I: Ascertain the feasibility of developing a high spectral purity, low noise THz source that can be reliably referenced (swept frequency mode) and locked (single frequency mode) to an external frequency standard or cavity with high fidelity. The source must be based on a demonstrated THz technology that can deliver a minimum of 1 microwatt continuously tunable over 0.1 THz somewhere in the 0.5 – 1.0 THz band. Define and assess all relevant performance metrics (e.g. power spectrum, lock stability, stabilized spectral bandwidth, amplitude and phase noise, etc.). A proof-of-concept demonstration of key components is encouraged. Finally, develop a plan, based on that THz source, which can span the entire 0.1 – 1.0 THz spectral region, either in one component or in multiple components stitched together.

PHASE II: Demonstrate and deliver a continuously tunable source technology with high spectral purity and low noise that can deliver a minimum of 1 microwatt over the entire 0.1 – 1.0 THz spectral region. The source must be able to operate in both swept and single frequency mode and must be reliably referenced and locked, respectively, to an external frequency standard or cavity with high fidelity. Quantify and demonstrate all relevant performance metrics. Such a well-characterized THz source would be delivered to the Army's Aviation and Missile Research, Development, and Engineering Center as part of the Weapons Sciences Directorate's Center for THz Technology.

PHASE III DUAL USE APPLICATIONS: Practical applications for THz radiation are now being seriously considered by the DoD and civilian sectors, including molecular spectroscopy for stand-off agent detection, imaging through obscurants, collision avoidance, high bandwidth burst communication, and atmospheric short range imaging and communications.

REFERENCES:
1. S. Albert. D. T. Petkie, R. P. A. Bettens, S. P. Belov, and F. C. De Lucia, Analytical Chemistry, "News and Features," Nov. 1, 1998, p 719A – 727A.
2. F. C. De Lucia and D. T. Petkie, Proceedings of SPIE, Vol. 5790, "Terahertz for Military and Security Applications III," p. 44 (2005).
3. E.R. Brown, K.A. McIntosh, K.B. Nichols, and C.L. Dennis, Applied Physics Letters, Vol. 66 p. 285 (1995).

KEYWORDS: Terahertz Source, Frequency Standard, Molecular Spectroscopy, Hyperspectral Imaging.

SB062-003 TITLE: High Temperature Corrosion Resistant Nanocomposite Materials for Turbine Engine Applications

TECHNOLOGY AREAS: Air Platform, Materials/Processes

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

OBJECTIVE: Develop materials and processing technologies for the fabrication of coatings and/or structural materials that allow longer-lived turbine engine performance at temperatures equaling or exceeding the peak values experienced in current military aircraft.

DESCRIPTION: State-of-the-art turbines use thermal barrier coatings based on zirconia but such coatings have limited durability (<10,000 hours) and constrain peak engine temperatures. Long-standing surface deposits can penetrate into the coating and result in hot corrosion, leading to premature spalling of the coating and failure of the engine. Recent advances in nanocomposite materials technologies may make it feasible to fabricate novel coatings that are corrosion resistant through a variety of nanostructure and nano-chemistry mechanisms. The novel nanocomposite coating developed in this effort will find extensive use in conferring corrosion resistance to alloy parts used in various fossil energy power generation devices. This will permit the simultaneous increase of turbine inlet temperature and the reduction of turbine cooling air, thereby increasing efficiency and saving capital costs. The use of higher turbine combustion temperatures will lead to fuel efficiency and reduction in toxic emissions, and will have broad dual-use applications.

PHASE I: Using a systems based approach, develop candidate nanocomposite thermal barrier coating system(s) including the bond coat for aircraft turbine engines. Identify suitable application/coating techniques. Utilize laboratory scale experiments to select coating systems and justify the transition to Phase II for conducting high temperature lifetime testing.

PHASE II: Develop and demonstrate the performance of the nanocomposite coating in a simulated environment such as hot burning in a stationary turbine. For example, coat actual engine hot section components such as turbine blades and conduct high temperature testing under simulated jet engine operating conditions using JP8 fuel. Demonstrate a 20% improvement in lifetime of the nanocomposite thermal barrier coating system over current state-of-the-art such as EB-PVD zirconia based coatings. Conduct post-test analyses to support subsequent transition and insertion into broad application.

PHASE III DUAL USE APPLICATIONS: This technology could be used in a broad range of military and civilian turbine engine applications due to both increased performance and reduced maintenance characteristics that may be achieved.

KEYWORDS: Nanocomposite, High Temperature, Coatings, Turbine Engine.

SB062-004 TITLE: High-Intensity, Narrow Emission FRET Probes for Single-Molecule Spectroscopy

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

OBJECTIVE: Develop high-intensity fluorescent probes with emission spectra that have a half-power bandwidth of less than 10 nm and output intensity that enables millesecond temporal and nm spatial resolution.

DESCRIPTION: Single-molecule spectroscopy based on fluorescence (Föster) resonance energy transfer (FRET) is a technique for measuring conformational changes in proteins. Recently these methods have been applied to the study of conformational changes during ion channel gating and to enzyme dynamics during catalysis. Military applications include the development of refined methods for rational drug design and rapid vaccine development for chemical and biological countermeasures. The temporal and spatial resolution of FRET techniques is currently limited by the output intensity of the probes and the 'spectrum crowding' that occurs due to the width of individual probe emission spectra. Temporal resolutions on the order of 10-25 milliseconds and spatial resolutions on the order of 1-5 nm is currently considered the state of the art in FRET-based measurement techniques. Increased output intensity will enable improved temporal resolution due to the reduction in time required to collect the requisite number of photons for accurate measurement. A narrowing of the emission spectra will enable an increase in the number of probes that can be measured simultaneously, thus enabling an increase in the number of protein degrees of freedom that can be measured in a single test. Advances in probe design will enable multiparameter analysis for single-molecule spectroscopy, which, in turn, will enable greater understanding of the link between protein structure and protein function.

PHASE I: Study the feasibility of developing additional FRET probes that enable a significant increase in output intensity and a half-power bandwidth of less than 10 nm. The feasibility study will examine issues such as synthesis techniques required to develop new FRET probes, requirements for rational probe design, and techniques for tagging proteins with the acceptor and donor molecules.

PHASE II: Develop design tools to predict probe intensity and emission spectra. Synthesize new probes and develop methods for tagging proteins. Demonstrate the use of the probes in multicolor FRET measurements of protein conformations with spatial resolution less than 1 nm and temporal resolution less than 1 millisecond. Quantify the benefit of increased spatial and temporal resolution on the analysis of protein conformations.

PHASE III DUAL USE APPLICATIONS: Single-molecule spectroscopy techniques with increased spatial and temporal resolution will yield new understanding of the relationship between the structure of proteins and their function. Military applications of this technology include the development of improved countermeasures to chemical and biological threats and the development of improved methods for rational drug design. Rational drug design, rapid vaccine development, and the development of new countermeasures will also yield commercial benefit in the pharmaceutical industry.

REFERENCES:

1. Lu, P., 2005, "Probing Single-Molecule Protein Conformation Dynamics," Acc. Chem. Res., vol. 38, pp. 557-565.
2. Harms, G, et al, 2003, "Probing Conformational Changes of Gramicidin Ion Channels by Single-Molecule Patch-Clamp Fluorescence Microscopy," Biophysical Journal, vol. 85, pp. 1826-1838.
3. Hohng, S., Joo, C., Ha, T., 2004, "Single-Molecule Three-Color FRET," Biophysical Journal, vol. 87, pp. 1328-1337.

KEYWORDS: FRET, Single-Molecule Spectroscopy, Protein Conformations.

SB062-005 TITLE: Portable Oxygen Generator

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: The objective of this research is to develop portable, light-weight, low power oxygen generators that are small enough to be carried by a medic in the far forward battlefield and which requires no logistical supplies or resupply.

DESCRIPTION: Today there are multiple types of oxygen generators, however all at too large and require significant power that their use in extreme environments such as the battlefield are not practical. DoD must have an oxygen generator which can be carried by the medic or can be incorporated into evacuation platforms such as Integrated Medical Systems Life Support for Trauma and Transport (LSTAT). To date, solutions with novel materials have nearly reached the limits for size and weight reductions, and continue to have major power requirements. Engineering solutions, such as much more efficient compressors, have potential to provide the required reductions. This specific topic deals with developing a portable oxygen generation system to replace currently used oxygen cylinders or other proposed systems which require some logistical support, such as fuel, chemicals, etc...

PHASE I: This phase is expected to produce an initial evaluation of candidate innovative solutions, a report of projected technical performance, and a design study for the device. This is a feasibility study for engineering systems, with innovative compressor designs being among the most likely candidates. Candidate designs will be evaluated for critical parameters (power, weight, size, compatibility with LSTAT, etc) (www.darpa.mil/dso has additional information about LSTAT,) with a minimum requirement 4 liter/min of continuous oxygen flow, weight less than 7 lbs and power requirement of less than 100 watts. A design study will be performed for the device with a projection of the performance parameters as indicated above.

PHASE II: The deliverable is a prototype oxygen generator, which can provide continuous oxygen flow at 4 liters/minute, weigh less than 7 lbs and draw less than 100 watts of power. This phase will fabricate a full size prototype system which does not need to be optimized for size. The critical issues will those indicated above. Complete documentation will be collected on materials properties, specifications, interface compatibilities, etc. Testing will be conducted to document performance. This will not be a clinically usable system, rather an engineering prototype that can demonstrate functionality and designs that indicate reduction to final product, including LSTAT compatibility.

PHASE III DUAL USE APPLICATIONS: One of the critical needs for wounded soldiers is a reliable, robust source of oxygen immediately after wounding and during evacuation. This device must be self contained in order to be available at a remote location. Not only would the candidate scan apply to casualties from the battlefield, but also provide the same capability for trauma care support during civilian injuries in remote areas, during disasters (where power and oxygen cylinders are not available or replenishable) and in every emergency room across the world. Phase III will address moving from initial prototype to fully integrate and reduced-size beta-prototype, as well as compatibility with LSTAT.

REFERENCES:
1. Hall LW, Kellagher RE, Fleet KJ. A portable oxygen generator. Anaesthesia. 1986 May;41(5):516-8.
2. Murray WB, Bhimsan NR, Rout CC. A laboratory assessment of oxygen delivery from a portable chemical generator. Anaesthesia. 1996 Dec;51(12):1127-8.

KEYWORDS: Oxygen Generator, Compressors, Medical Evacuation, Manufacturing.

SB062-006 TITLE: <u>Productivity Advancements for Configurable Computing (Field Programmable Gate Arrays (FPGA))</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Identify and evaluate advanced application development tools and approaches for reconfigurable computing and specifically Field Programmable Gate Arrays (FPGA) to establish DoD application critical reconfigurable computing productivity and application efficiency.

DESCRIPTION: Critical DoD processing applications often require unique and specific processing implementations. General purpose processors architectures often are ill suited to perform specialized processing or simply can not meet the performance requirements necessary for a DoD application. Custom circuitry that could provide the required performance is prohibitively costly and requires significant development and fabrication time, and as a result is unavailable to provide required processing solutions. As a result, a significant number of DoD applications turn to FPGAs as a computational solution. FPGAs can be uniquely configured to perform specific processing implementations, are commercially available, and do not require custom fabrication times or cost. However, FPGAs have several limitations themselves – lower efficiency than custom implementations, higher power than custom implementations, and difficulty and complexity for programmability. Specifically the difficulty to program and implement FPGA solutions is a key issue to DoD application developers and drive application cost and schedule.

While the Polymorphous Computing Architectures (PCA) program and follow on efforts are addressing these issues from a new architectural approach, FPGA solutions will continue to be critical for many DoD applications to provide cheap, near-term, customizable processing solutions. This activity proposes to specifically address the difficulty to program and utilize FPGA implementations. Currently development tools for FPGAs are limited in scope, characterized is hard to use, and requires detailed hardware knowledge of the FPGA. The application and algorithm developer are separated from the implementation as a result, leading to inefficiencies, incorrect implementation, and unacceptable development times. These issues will be addressed by this effort. Development tools and approaches to advance the development and programmability of FPGAs and enable critical DoD application implementations will be identified and evaluated.

This SBIR topic will identify, evaluate, and propose further advancements in FPGA application and implementation development tools and approaches and develop these toward a complete development environment that will allow high level, application developers to transition application designs efficiently onto FPGA implementations without requiring detailed hardware knowledge of the implementation or difficult and error-prone intermediate transitions. This will significantly advance and enable the rapid and efficient implementation of unique DoD application processing and improve processing development productivity and efficiency.

PHASE I: Identify and select advanced and developing FPGA development tools and approaches. Evaluate the selected development tools and approaches within the context of DoD processing development. Establish productivity metrics for the evaluation of the development tools and approaches identified relative to current FPGA development approaches and implementations. Evaluate the potential for the proposed tools and approaches for the improvement of DoD FPGA processing productivity and application development. The final element of Phase I will be the develop a detailed plan for the utilization and transition of the tools and approaches selected and evaluated for further development within an overall FPGA and application processing environment. Phase I performers will coordinate with the PCA Morphware Forum (mark.richards@ece.gatech.edu, 404 894-2714, Georgia Institute of Technology) to stay cognizant of how the tools and approaches being addressed could be integrated into a more comprehensive development environment.

PHASE II: Develop and mature the successful tools and approaches selected from Phase I toward DoD application use and potential commercially supported implementations. The tools will be matured to the point where they can be distributed and utilized for evaluation and test-site use. The selected Phase II efforts will transition tools to selected DoD developers and support their evaluation and potential use. Using the metrics developed in Phase I the tools will be evaluated and FPGA programmability productivity improvements documented. The tools and approaches will be developed as initial implementations and to the point of full development and release. The Phase II performers will coordinate with the PCA Morphware Forum to establish how the tools and approached being developed can be integrated into the PCA Morphware Forum development environment.

PHASE III DUAL USE APPLICATIONS: Tools and programmability approaches developed will be integrated into existing FPGA and system processing development environments. Tools and programmability approaches will be integrated into and transitioned into commercially viable tools sets and development tool ensembles such as high performance medical systems and navigation. The tools and tools sets will be made available and transitioned to actual DoD applications for use in efficient development of FPGA processing implementations and for greatly improved DoD processing development productivity and efficiency.

REFERENCES:
Special Technology Area Review on Field Programmable Gate Arrays (FPGAs) for Military Applications, Report of Department of Defense Advisory Group on Electron Devices (AGED) (Office of the Under Secretary of Defense Acquisition, Technology & Logistics), July 2005.

KEYWORDS: Development Tools, Productivity Tools, Reconfigurable Processing Productivity, FPGA.

SB062-007 TITLE: Extremely Low Attention Demand Information Systems (ELADIS)

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop approaches to providing information to human actors in such a way as to require extremely low demands on their attention and cognitive processes. Low cost, portability and low initial training and instrumentation costs are secondary objectives.

DESCRIPTION: The amount of information which soldiers must learn, review and maintain awareness of is ever-increasing. The ability to process information with extremely low demands on cognitive and attentional resources would be useful across a huge range of situations and domains. For example, soldiers en route to a mission deployment could brief or rehearse mission-specific information while "on the march" or in transport. Alternatively, soldiers engaged in complicated navigation, planning and coordination tasks could nevertheless maintain awareness of critical vehicle and mission performance parameters and be able to readily detect when such parameters begin to deviate from expectations and be immediately aware of available courses of action all without losing focus on other, ongoing tasks.

Recent advances across multiple fields ranging from augmented cognition technologies to novel display design approaches provide various techniques that could be brought together to create novel, human-focused ELADIS systems. The goal of this research will be to discover and develop techniques to improve the "bandwidth" of useful information transfer for the expenditure of available attentional resources. Particularly of interest are approaches whose demands on attentional resources are as insignificant as to go unnoticed by the information receiver and/or to produce negligible degradation of other ongoing tasks. ELADISs might operate by being aware of and managing available resources so as to provide training or refreshing information only when sufficient resources may be diverted from other tasks to process it. Additionally, approaches which make use of optimal modalities (or combinations of modalities) and/or more effective information presentation methods and/or effective cognitive preparation for information uptake might serve to reduce the proportion of attentional resources required to process required information. Finally, novel approaches might make it possible to make use of resources in contexts and conditions where they were previously deemed unavailable or insufficient (e.g., extreme fatigue or degraded consciousness states). Other approaches and/or combinations of approaches which accomplish these ends are welcome.

PHASE I: Design an approach to providing a practical ELADIS system with the potential for utility in a military domain of interest. Define performance metrics and testing procedures to demonstrate improvements over current state of the art information presentation approaches. Provide an initial test demonstrating the utility of the approach.

PHASE II: Develop a prototype of the ELADIS approach and demonstrate it in a domain with at least moderate fidelity. Verify that the approach provides improvements in information uptake in a range of application situations or contexts.

PHASE III DUAL USE APPLICATIONS: The development of effective approaches to providing more information with no increase in attentional processing requirements could revolutionize a very wide range of commercial applications from aviation through manufacturing to process control and power generation. In all cases, the ability to more effectively use human cognitive resources could result in reduced requirements for training times and, potentially, reduced manpower requirements - with associated reductions costs.

REFERENCES:
1. Wickens, C. and Holland, J. (2000). Engineering Psychology and Human Performance, 3rd. Ed. Prentice Hall; Upper Saddle River, NJ.
2. Burns, C. and Hajdukiewicz, J. (2004). Ecological Interface Design. CRC Press; Boca Raton, FL.
3. Maybury, M. and Wahlster, W. (1998). Intelligent User Interfaces. Morgan Kaufman; San Francisco, CA.

KEYWORDS: Attention, Workload, Cognitive Processing, Information Management, Multi-Modal Displays, User Interface Design.

SB062-008 TITLE: <u>Distributed Cooperative Human Agent Problem Solving</u>

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Conduct research and develop technologies for creating distributed systems of humans and software agents that work cooperatively to perform militarily relevant tasks.

DESCRIPTION: To get the most out of human resources, the US military makes use of network access to enable distributed human experts to collaborate. Even tools as basic as email and online chat systems have proven to be great force multipliers in a wide range of settings from logistics management to air operations centers.

This topic focuses on the next generation of online collaboration – distributed collaboration between human parties and sophisticated software systems or "intelligent agents." While generalized software intelligence is still very far away, recent advances have made it possible to create automated systems that perform sophisticated tasks in specialized domains, e.g., weather analysis to support air operations planning. When such domain dependent or specialized intelligent core programs are combined with sophisticated software for communication, information sharing, reasoning about time, dealing with world dynamics, etc., they are called intelligent agents.

For this topic, we seek proposals to create intelligent problem solving networks consisting of humans and intelligent agents. Conceptually the idea is to create a problem solving Internet where expertise is shared in a collaborative fashion across a dynamic organization that is formed in response to a given need or request. The goal is to leverage the distributed human expertise to the nth degree by allowing experts to flexibly and dynamically interact with each other and with intelligent agents to solve problems. Conceptually the model is to have a pool of human experts and intelligent agents, all specializing in a particular areas, and then to have outside clients (e.g., commanders) submit work to the pool of experts and have the pool of experts dynamically organize and perform the work or solve the problem. Note that in the long term vision, this pool of experts may not be a dedicated resource of the network, i.e., these human experts may have multiple roles in multiple organizations and participate in a given problem solving session on an as needed / as appropriate basis.

Proposed research should focus on the basic human/agent collaborative problem solving issues. Examples include information sharing between humans and agents (low level, intermediate, results, etc.), joint problem solving, joint goals, mixed initiatives, adjustable autonomy, ontology for the specialized domain, distributed autonomous progress tracking, role assignment, capabilities descriptors, etc. Proposers may suggest other novel areas of research. The goal of the work, however, is to create a usable tool in a specialized domain. Proposers may choose the domain, though domains that are militarily relevant are preferred. The domain or candidate domains should be specified in the proposal. Research in ancillary areas such as match-making, distributed resource finding, or how to dynamically organize humans and agents for problem solving is relevant and possibly of interest though is secondary to the basic human/agent collaboration issue.   Proposers should leverage or build on prior art.

PHASE I: Assess feasibility of proposed technical solution by constructing elements of a human / agent problem solving network. Use assessment to refine the proposed application domain and the intelligent agent technologies that will be brought to bear.

PHASE II: Fully develop the technical approach to produce a high quality system for human / agent collaborative problem solving.

PHASE III DUAL USE APPLICATIONS: The technology developed in this topic is applicable to a wide range of military and civilian/commercial applications such as distributed collaborative engineering design, intelligence analysis, business data analysis, distributed medical diagnosis, etc.

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KEYWORDS: Agents, Cognitive Systems.

SB062-009 TITLE: Specialized Robot / Human Teams for Limited Tactical Maneuvers

TECHNOLOGY AREAS: Information Systems, Ground/Sea Vehicles, Human Systems

OBJECTIVE: Research and develop technologies to support a multi-robot / multi-human team that works cooperatively to perform a specialized tactical maneuver or maneuvers.

DESCRIPTION: Recent advances in joint goals, multi-agent planning, and coordination make it possible for multiple autonomous systems to work cooperatively to perform coarse grained tasks. Such technologies are often applied to autonomous software systems rather than robotic systems because limitations in other areas such as computer vision or effector dexterity prevent robotic teamwork in very general or unconstrained settings. Open or unconstrained environments can similarly impede the online planning or coordination algorithms that might be used to control the robots. However, in properly scoped and constrained environments, e.g., robotic soccer, the sensor issues and the planning/control issues are controlled enough to yield reasonable proof of concept results for robotic teamwork.

This topic seeks new research in the joint space of sophisticated software control and robotic systems. The challenge is to create a system demonstrating the use of multiple robots with one or more humans on a highly constrained tactical maneuver. The maneuver can be selected by the proposers. One example of such a maneuver is the through-the-door procedure often used by police and soldiers to enter an urban dwelling. This maneuver generally involves multiple parities who work in concert, e.g., one kicks in the door then pulls back so another can enter low and move left, followed by another who enters high and moves right, etc. In this project the teams will consist of robot platforms working with one or more human teammates as a cohesive unit. The robots should be under autonomous control rather than remote / teleoperated.

Proposers can make simplifying assumptions when selecting the maneuver and can assume a simplified environment, e.g., no steps leading up to the door. Environmental characteristics can also be simplified, e.g., robot controllers do not need to plan or coordinate in completely unconstrained settings.

The human(s) should have an active role in the maneuver. For instance, if one views the team as all sharing the same plan, one step in that plan may involve the human performing some human specific task, e.g., instructing the robots where to stand initially relative to the door or using the (better) human visual system to indicate where on the door the first robot should apply pressure in order to open or break the door. Proposals that focus on interdependent tasks between the human and robots will be preferred, i.e., where the human and robotic platforms must operate as a team on concert.

Simplifying assumptions can be made about the physical strength of the robots, e.g., robots do not need to break down the door but may simply apply pressure to open it. A non-realistic scale may be chosen for this project, i.e., smaller robots may be used, to avoid large overhead cost in platform development. Off the shelf and relatively inexpensive robot platforms are acceptable.

Safety should be explicitly designed into the system, e.g., via system kill switches and physical sensors as well as safety subroutines in the software control.

The output of this project will be a demonstration / proof-of-concept of robot human teamwork for tactical settings plus research insights gained by trying to leverage existing work in solving these problems. Military applications are obvious. Non tactical applications include inventory management (e.g., robot / human "picker / packer" systems), factory floor task performance, and limited crisis response maneuvers.

PHASE I: Assess feasibility by developing approach or elements of the approach. Leverage initial development to improve technical approach for Phase II, i.e., use experience to identify areas of refinement for algorithms, software architecture, hardware platforms, and the tactical maneuver being implemented.

PHASE II: Fully develop the technical approach to produce a high quality system for robot / human teaming on a tactical maneuver. Host a demonstration for the technical POC. Create a video presentation/movie of the system in action. Document technical approach and document lessons learned.

PHASE III DUAL USE APPLICATIONS: Leverage research investment to develop dual use for the technology. The technology developed in this topic is applicable to a wide range of military and civilian/commercial applications, e.g., tactical military maneuvers in a field setting, factory floor task performance, automated inventory picker systems, emergency response, etc.

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KEYWORDS: Robots, Agents, Cognitive Systems.

SB062-010   TITLE: <u>Anomaly Detection</u>

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop sensor resource management, data exploitation and classification algorithms for the automatic detection of anomalous activities in cluttered environments using imaging and moving target indication (MTI) sensors.

DESCRIPTION: The idea of using data products from existing and future intelligence surveillance and reconnaissance (ISR) systems to develop models of normal background activity, i.e. modeling the clutter, has received considerable interest of late. The use of these normalcy models should allow for the detection of anomalous events which can be subsequently investigated to determine their military significance. Innovative system concepts which support closed-loop sensor control for unsupervised training and application of anomaly detection algorithms are encouraged. These concepts should provide a solid theoretic framework for control, modeling and detection and be adaptable to various applications including urban ground surveillance using combinations of ground, air and space-based radar, electro-optical and infrared images and MTI.

PHASE I: Develop or adapt modeling and simulation resources to quantify the capabilities of the proposed system to characterize normal activities and detect anomalous events. Specifically quantify the capabilities of the system to detect and characterize according to the nature of the anomalous behavior observed. Anomalous behaviors could include coordinated sub-group activities within a larger group, individuals "going against the tide", reactive behavior of groups of individuals and anticipatory behavior (e.g. rapid clearing of a street). Develop a system concept and conduct the relevant performance tradeoff analyses.

PHASE II: Develop a prototype system based on the Phase I concept suitable for field testing. Demonstrate the performance of the system against wide ranges of normal and anomalous activities. Demonstrate the capabilities of the system to reactively define "normal" based on the context as sensed and based on macroscopic situational parameters, i.e. geographic location, operational context and local cultural norms. In the event the proposed system concept involves sensors beyond the control of the bidder, develop and execute a test plan in cooperation with the Government. Pursue technology insertion opportunities into current and future military ISR systems.

PHASE III DUAL USE APPLICATIONS: The system and/or technology could potentially be employed in numerous military ISR systems including ground-based, air- and space-borne assets. The technology would afford the military a new and/or improved capability to detect and anticipate enemy activities within an environment cluttered by friendly or neutral activities. Potential commercial applications include remote sensing for homeland security and law enforcement.

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KEYWORDS: Anomaly Detection, Normalcy Modeling, Statistical Pattern Analysis, MTI, Sensor Resource Management.

SB062-011 TITLE: <u>Moving Target Detection, Classification and Identification in Urban Warfare Environments</u>

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop sensor technologies and/or data exploitation algorithms that enable high-confidence detection, classification and identification of the moving vehicles and/or humans involved in activities of interest by sensing discriminating signatures and/or spatiotemporal changes.

DESCRIPTION: There exist a growing number of sensor systems capable of detecting and tracking moving vehicles and humans. Reconnaissance and surveillance in urban environments is challenging for these systems due to their limited line-of-sight visibility and the complex "clutter", i.e. background activity. Reliable tracking and reconnaissance through the urban landscape requires high-confidence identification and/or powerful discrimination information which can be efficiently sensed and used to associate the moving target detections obtained across varying time scales. Moving vehicle and human targets exhibit numerous observable signatures attributed to both their construction (mechanical or physiological) and peripheral equipment which may be exploited by remote sensors for detection, classification and identification. Of particular interest are those sensor modalities and signatures which are obtained via spatiotemporal change detection techniques that can be reliably employed at operationally significant ranges and environmental conditions, i.e. weather. Innovative concepts for sensor design, data exploitation and signature fusion techniques that result in high-confidence detection, classification and/or identification of moving vehicle and human targets are encouraged.

PHASE I: Develop or modify modeling and simulation resources so that the capabilities of the proposed system can be determined. Using those resources quantify the ability of the proposed system to detect, classify or identify vehicles and/or humans in urban environments. If applicable, distinctly distinguish between classification and identification functions and quantify the impacts on each of incomplete target models or templates. Quantify the capabilities based on operational ranges and on the impact of the varied environmental factors present in the urban environment. Based on the modeling and simulation develop a system concept and conduct the relevant performance tradeoffs.

PHASE II: Develop a prototype system based on the Phase I concept suitable for field testing. Conduct field tests of the prototype in urban environments representative of those found during military operations. Demonstrate the system's capabilities against vehicle and/or human targets in a variety of urban terrains that reflect distinct operational contexts for the system. In the event the proposed system concept involves sensors beyond the control of the bidder, develop and execute a test plan in cooperation with the Government. Pursue technology insertion opportunities into current and future military intelligence, surveillance and reconnaissance (ISR) systems.

PHASE III DUAL USE APPLICATIONS: The system and/or technology could potentially be either fielded separately or employed in numerous military ISR systems including ground-based, air- and space-borne assets. The technology would afford the military a new and/or improved capability to maintain situational awareness in urban warfare environments. Potential commercial applications include remote sensing for environmental monitoring, homeland security and land-use analyses.

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KEYWORDS: Human Identification, Urban Sensing, Change Detection, ISR.

SB062-012 TITLE: <u>Computer-Assisted Negotiation for Distributed Logistics</u>

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Design and develop a computerized system to assist parties with different interests to negotiate a fair division of resources and tasks without having to make those interests public.

DESCRIPTION: Future US military operations will require intense collaboration across services and agencies and increasingly will need to leverage the resources and infrastructure of the commercial sector to satisfy operational requirements. To achieve successful collaboration in the context of a military operation, these autonomous entities (which have their own sets of interests and operating constraints) need to be able to cooperate, coordinate and negotiate effectively. Traditional centralized optimization approaches for solving this class of dynamic resource allocation problems typically decompose what is known as a master problem into subproblems, each of which is optimized subject to a local resource budget assigned by the system. Each subproblem yields a local solution as well as a sensitivity analysis (called dual variables) that is used to modify the local budgets iteratively to improve the solution with respect to global goals.

These centralized approaches suffer from several weaknesses in practice: (1) the computational time can scale poorly with the number of iterations and subproblems; (2) entities represented by a given subproblem (e.g., a commercial air carrier participating in a military airlift) may not want to reoptimize over multiple budget scenarios or share information that can aid a competitor; and (3) the solution is fragile to uncertainty in the environmental state, which may require repeating the optimization process (often from scratch) as changes occur over time.

DARPA seeks distributed algorithms and negotiation protocols (rules of interaction among entities) for performing dynamic resource and task allocation among autonomous parties that do not share the vulnerabilities of centralized algorithms and have relevance to DoD problems. There has been prior work in dividing goods or resolving conflict among autonomous parties [1, 2, 3] and in designing domain-specific negotiation protocols [5], including DoD applications [4]. However, what is needed is a more general methodology for designing negotiation protocols appropriate for a given operational setting. In addition to specifying how members can interact and the obligations each member has with respect to satisfying the group objective, the methodology should include the system properties (such as efficiency, stability, simplicity and symmetry) associated with a given set of protocols. There also needs to be a complementary infrastructure to perform the negotiation, which may include an auction infrastructure for different bidding mechanisms or a trading infrastructure by which members can propose an exchange of a subset of resources and tasks of another member.

Successful completion of this research will greatly facilitate real-time logistics, allowing optimizations to be more robust, more responsive to environmental changes, and better able to leverage the "best practices" of the individual members without having to integrate those practices into military systems or to share the expertise with commercial competitors.

PHASE I: Assess feasibility of proposed approach by developing and evaluating a subset of the negotiation protocols proposed. Identify any improvements / refinements to overall technical approach that will be addressed in Phase II.

PHASE II: Fully develop the protocols and supporting software and demonstrate protocol generality and effectiveness in multiple applications.

PHASE III DUAL USE APPLICATIONS: Leverage prior investment for dual use. Successful completion of this research will have many applications, including the buying and selling of goods and services across multiple vendors, commercial logistics, military logistics, and distributed sharing of information.

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KEYWORDS: Collaborative Planning, Distributed Algorithms, Real-Time Deconfliction, Dynamic Resource Allocation, Negotiation Theory, Game Theory.

SB062-013 TITLE: <u>Kilowatt-Class, Chip-Scale, Laser Diode Phased Arrays</u>

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

OBJECTIVE: Demonstrate high brightness, coherent laser diode phased array technology that can ultimately be scaled to kilowatt average power levels and beyond

DESCRIPTION: The objective of this effort is to develop the technology necessary to provide robust phasing of large (1000 individual emitter) arrays of efficient (>35%), high power (>1 watt), single mode laser diodes. Despite considerable efforts within the DoD over the past two decades, this objective has never been met. While large arrays of low power (1-10 milliwatts) have been demonstrated, these efforts have resulted in total coherent average power levels of only 10s of watts.

In this SBIR effort, DARPA is interested in understanding the technical issues that have prevented diode laser researchers from achieving robust phasing of large arrays of high power laser diodes, and then in developing new insights, technologies and approaches which can avoid these limitations and lead to the desired high power coherent array performance. The primary results of this SBIR program will be a set of experiments that convincingly demonstrates these new, scalable technologies and approaches.

The Phase 1 proposal should clearly discuss the shortfalls of past approaches, and clearly distinguish the newly proposed approaches from these past approaches. The Phase I proposal should also provide experimental data and/or calculations which support these new approaches.

PHASE I: Design a feasibility experiment that will demonstrate that the proposed approach can lead to robust, scalable, high brightness laser diode phased arrays. Experimental evidence that the selected approach will ultimately meet the objectives of this SBIR effort is desirable.

PHASE II: Demonstrate experimentally that an array of 20 high power, single mode, laser diodes can be coherently combined to produce a single near-diffraction-limited output beam at a power exceeding 20 watts. Achieve this demonstration with a technology that is scalable to the coherent combination of 1000s of high power (>1-watt) laser diodes.

PHASE III DUAL USE APPLICATIONS: Kilowatt-level, chip-scale, coherent laser diode arrays will find application in a broad range of military systems including laser radar, laser target designators, laser illuminators, and ultimately in High Energy Laser weapons. In the commercial sector, these phased arrays will be useful in a variety of systems ranging from material processing to laser welding and cutting.

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KEYWORDS: Laser Diode Array, Laser Diode.

SB062-014 TITLE: Optical Modulator Bias Control for Analog Fiber Optic Link Applications

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Develop small form-factor bias control of optical modulators suitable for high dynamic range analog fiber optic links useful for surveillance and communications applications.

DESCRIPTION: While optical modulators with integrated bias control for digital fiber optic link applications are commercially available, integrated bias control for analog fiber optic link applications are not commercially available. For digital links, bias control accuracy is not critical. In contrast, the spurious free dynamic range of an analog fiber optic link is critically dependent on the accuracy of the bias control. For the case of Mach-Zehnder intensity modulators biased at quadrature, bias accuracy of less than 1o is often needed to meet the linearity requirements of wideband surveillance applications. Electronic bias control circuits typically apply a low frequency dither signal to the modulator, and lock onto the quadrature point by minimizing the 2nd harmonic of the dither signal via a feedback loop. The spur free dynamic range (SFDR) of the link is limited by both error in locking onto quadrature, and by intermodulation of the dither signal with signals of interest (which cause in-band spurious signals). As such, it is desirable to minimize the modulation index (< 0.01%) of the dither signal so that the dynamic range of the link is not limited by intermodulation of the dither signal. Finally, in order to maintain the optimal link gain, it is important to minimize the fraction of the optical power diverted from the signal path to the bias control feedback loop.

Improvements in lasers, optical modulators, and photodetectors are enabling application of analog fiber optic link technology to a wider range of commercial and military RF systems with critical noise figure and SFDR requirements. The availability of integrated bias control for analog links will accelerate the adoption of RF-over-fiber technology. This topic seeks innovative approaches to optical modulator bias stability, either through intrinsic design or electronic control. Performance goals for the integrated bias control should include bias control error < 1o, an operating temperature range from -45o C to +85o C. It should be expected that the modulator will operate with optical input power between 16 dBm and 22 dBm. A candidate optical modulator with which the bias controller should operate is expected to have an optical insertion loss (including bias control tap loss) < 4 dB, a Vƒà

< 4.5 V and a modulation bandwidth from 30 MHz to 18 GHz. The volume of the packaged integrated modular with bias controller shall be no greater than twice the volume of a similar modular without integrated bias control.

PHASE I: A detailed design study of the proposed approach shall be performed in which the predicted performance is measured against the performance goals outlined above. For novel self-biasing approaches, material properties (e.g., pyroelectric charge generation) and device design (e.g., symmetry) relevant to self-biasing operation shall be studied in detail. Preliminary measurements and demonstrations showing feasibility of the approach are highly encouraged.

PHASE II: Prototypes shall be fabricated to demonstrate the validity of the design. The phase-II prototype will not be required to meet the size requirement (e.g., full integration of electronics into the package is not required). The prototype shall be tested in an RF photonic link, relevant measurements (e.g., link gain, SFDR) over the full required temperature range shall be performed.

PHASE III DUAL USE APPLICATIONS: The technology developed can be utilized in commercial antenna remoting applications, such as radio over fiber or telemetry antenna remoting, as well as military antenna remoting systems.

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KEYWORDS: Optical Modulators, Photonics Links, Analog Links, Antenna Remoting, External Modulation, Microwave Photonics, Fiber Optics.

SB062-015 TITLE: Silicon-Based Infrared Imaging Sensor

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Develop an approach and a technology process for making infrared imaging sensor systems-on-a-chip (SOC) fabricated from Silicon Germanium (SiGe)/Si materials. The SiGe infrared sensor systems should be capable of adequately substituting for mid-wavelength infrared (3 - 5 microns) imagers and sensors made from such exotic materials as Indium Antimonide (InSb) or Mercury Cadmium Telluride (HgCdTe).

DESCRIPTION: Current infrared imaging systems, missile guidance sensors, and threat detection sensors are made from InSb or HgCdTe materials. Sensor systems based on these materials are expensive because of the difficulties of synthesizing and processing the materials. The HgCdTe materials system, for example, can only be grown on small size substrates. A resulting wafer with device structures on it is then difficult to process into sensors because of the softness of the material; this is a consequence of the relatively weak atomic bond between atoms of Mercury and Tellurium in the compound material. Once fabricated into sensors, the resulting component then must be cooled to cryogenic temperatures for optimal operation. Since signal conditioning and processing electronics cannot be made from the same materials, silicon electronic read-out chips must be hybridized with the InSb or HgCdTe sensor devices, adding to the complexity and cost of the sensor system. The popularity of these exotic infrared materials is due to their high sensitivity to radiation covering the spectral bands from 3 -5 and 8 -12 microns. All blackbodies (warm to hot objects), however, emit large quantities of infrared photons ranging in wavelength from about 0.9 to 12 microns. The quantity of infrared photons in the near-infrared (0.9 – 2 microns) is relatively small compared to what it is at the mid- to long-wave region of his spectrum. It is therefore feasible to extract a weak signature from a warm body by using detectors that operate in the 0.9 – 1.5 micron region.

This topic seeks concepts in advanced infrared sensors that are based on SiGe technology, a material which has primarily been used for Bipolar - Complementary Metal-Oxide Semiconductor circuits (BiCMOS) and Very Large Scale Integration (VLSI) digital chips. SiGe is also known to be a good optical detector with a spectral peak at the infrared wavelength of 1.3 micron, and could therefore be used to detect the scarce photons emitted by warm bodies in the absence of or in lieu of an optimal InSb or HgCdTe detector at the mid-wave band. Concepts proposed for the near-infrared SiGe sensors should seek to exploit the advantages of this material. Such advantages include room-temperature operation, compatibility with mainstream CMOS technology and therefore the potential to include sophisticated signal conditioning and processing electronics on the same chip as the sensor.

PHASE I: Conduct feasibility study of an infrared sensor based on SiGe material and its ability to detect photons emitted by a warm or a hot body. Conduct simulations to compare the sensitivity of the SiGe detector at its peak wavelength (of 1.3 microns) to an InSb detector at its peak mid-wavelength (of 4 microns).

PHASE II: Design, develop, and fabricate the prototype single-pixel device proposed in Phase I. Demonstrate and measure its sensitivity to a warm object in a laboratory environment. Characterize the device completely. Using the results of the characterization experiments, refine the prototype design and fabricate several array sizes (16 x 16, 32 x 32, 64 x 64) with signal conditioning and processing electronics on-board. As applicable, develop packaged standard sized arrays (128 x 128 and 640 x 640) of infrared imaging sensor systems-on-a-chip. Demonstrate operation in typical DoD application areas.

PHASE III POTENTIAL DUAL-USE APPLICATIONS: Infrared imaging sensors have many applications in the military and commercial world. The most obvious applications include night vision for vehicles, medical thermography for cancer or tumor detection during diagnosis or surgery. Other applications include robot vision in industrial automation.

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KEYWORDS: Infrared Imaging, Silicon-Germanium, Low Cost Sensor.

SB062-016 TITLE: Electro-Optic Polymer Based Ultra-Linear Directional Coupler

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Design, fabricate, and demonstrate a low optical loss polymer directional coupler modulator which has a fiber to fiber optical loss that does not limit device performance across a range of frequencies.

DESCRIPTION: Microwave/millimeter wave technology is presently a mature technology. Monolithic components allow for high signal to noise ratios to be achieved. However, the necessity of down conversion from the high frequency carrier to an intermediate frequency before digitization and/or further processing limits the effective dynamic range that can be achieved by purely microwave/millimeter components.

The development of low loss, low dispersion, and low loss optical links coupled with the linear response of optical detectors to the intensity of incident light stream would make optical links an attractive alternative to microwave/millimeter links. These technologies could be employed in remote transmission and signal preprocessing if the optical intensity modulator can be made to match (1) the rest of the optical system, and (2) the optical-to microwave/millimeter wave down conversion.

PHASE I: Feasibility Study to demonstrate low-optical loss polymer materials with r33 values on the order of 100 pm/V and an optical loss of ~ 2dB/cm.

PHASE II: Develop prototype polymer modulators with high r33, low optical loss materials and demonstrate the following:: (1) polymeric materials with optical loss less than 1.5 dB/cm, (2) demonstrate a 2x decrease in the dc drift over state-of-the-art LiNbO3 optical modulators and switches, (3) demonstrate low loss coupled links as part of modulator design and (4) demonstrate scalability of the design and process for fabricating selected modulator devices and materials.

PHASE III DUAL USE APPLICATIONS: The military applications of this technology included improved broadband performance of modulators for communications and radar systems. Commercial applications will be primarily focused on improved bandwidth for communications infrastructure and equipment as well as communication electronics.

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KEYWORDS: Polymer Modulators, Low-Loss Optical Polymer Materials, Multi-Stack, Polymer Waveguides.

SB062-017 TITLE: Integration of Ultra-High-Q Microresonators with MEMS for Tunable Coupling

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Design and fabricate an adaptive filter based on ultra-high Q optical resonators and waveguides. The resonator- waveguide coupling should be adjustable on a timescale of microseconds by an appropriate on-chip MEMS structure.

DESCRIPTION: Light can be confined by resonant recirculation in toroidal microcavities with very small volumes. An ideal cavity would confine light with very low loss (for a long time) and would have narrow resonant frequencies at precisely defined values, with the number of resonances inversely proportional to the cavity volume (V). Real cavities are described by the cavity Q factor, which is proportional to the confinement time in units of optical period, and the volume V. Since in most microcavities optical trajectories occur near the surface, their performance strongly depends upon interface quality and the degree of surface smoothness. Using combinations of Si and SiO2, materials compatible with silicon microelectronics, microcavities with Q~5 x 107 have been prepared. [1]

Many applications of high-Q resonators depend on transfer of optical power between the resonator and an adjacent waveguide, or between pairs of waveguides. For resonant power transfer with high efficiency the resonator-waveguide coupling coefficient must be greater than the intrinsic round-trip loss of the microcavity. An example of such a device would be a low-loss four port resonant optical coupler based on toroidal microcavities with a loaded Q (defined as the overall quality factor of the resonator including coupling to waveguides) greater than 106. [2] In addition to forming narrow band filters such devices offer inherently highly dispersion allowing for sophisticated manipulation of the phase or group delay response.

The current effort will add the ability to couple and decouple the resonator and waveguides on microsecond timescale by means of an appropriate MEMS structure. This capability would be useful in adaptive wavelength/phase filters.

PHASE I: Define and model the performance of a waveguide-resonator system with emphasis on phase and group delay dispersion.

PHASE II: Develop a prototype device to be fabricated with a Complementary Metal-Oxide-Semiconductor compatible process. Conduct testing of a completed device and compare results with the model developed under Phase I.

PHASE III DUAL USE APPLICATIONS: This filter could be used in a broad range of military and civilian applications where resonant and adaptive light filters are used – for example, in optical signal processing, biosensing, and non-linear optics.

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KEYWORDS: High-Q microcavity, Resonant coupling, Adaptive filters, MEMS

SB062-018   TITLE: Multi-Sensor Weapons Detection

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop high-volume sensor portals for detecting concealed or vehicle-borne weapons or explosives in heavy clutter backgrounds.

DESCRIPTION: There has been a great deal of interest in single-mode solutions for weapons detection, ranging from video, thermal, IR, passive terahertz, and millimeter wave radar to name just a few. All of these have had issues with discriminating targets in very heterogeneous background environments. This activity will integrate one or more promising sensor approaches into a multi-mode, multi-sensor solution targeted at improved discrimination of concealed or vehicle-borne weapons. Innovative approaches might include hierarchical detection approaches, and multi-aspect or tomographic imaging. Success will require high detection probability with false detections under 0.1% or less.

PHASE I: Conduct a feasibility study on the sensor phenomenology and discrimination to extract difficult target signatures of concealed or vehicle-borne weapons or explosives in heavy background interference. Demonstrate unique detectable signatures and show expected background levels in operational environments. Acceptable detection modes should include multi-sensor/multi-mode fusion of active or passive, tomographic or transmissive sensors.

PHASE II: Develop the technology identified in Phase I and demonstrate a proof-of-concept laboratory experiment showing detectable metrics with relevant background interference. Devise potential concepts of operations for field use at check points or entry barriers.

PHASE III DUAL-USE APPLICATIONS: This system would have immediate dual-use applications in both military and civilian applications, including homeland defense, regional security at high volume functions and public facilities, and coastal and border protection.

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KEYWORDS: Weapons Detection; Sensor Fusion; Multi-Mode Discrimination.

SB062-019   TITLE: Chemically-Driven Light Sources

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors, Electronics

OBJECTIVE: Develop revolutionary light sources that are powered by energetic chemical reactions. There is interest in broadband (UV to IR) single flash, continuous wave (CW) and modulated CW devices. These devices will replace current electrically powered devices and must provide a package that is smaller and lighter while being spectrally brighter.

DESCRIPTION: There is a need for intense sources of light, for a variety of applications, across the entire spectral range from ultraviolet through the infrared. Examples of applications include; stimulation for sensing and detection of chemical species, covert illumination for night time operations, beacons to mark terrain or other specific features of interest, and communications. These applications are currently being served by electrically powered lamps and lasers. The power sources of these devices dominate the size and weight of the package. The goal of this effort is to develop chemically-driven illuminators that can replace electrical devices at much reduced size and weight by using the power produced by a chemical reaction. Additionally, these devices should provide a much more intense broadband photon flux. There are applications for devices that produce; an extremely high photon flux in a single short pulse, extended CW emission, and temporally and spatially modulated emission. Control and stability of the output wavelength band is a critical requirement.

PHASE I: Develop a methodology to design and produce chemically-driven light sources with a broad range of wavelengths and output types. Demonstrate effectiveness through analysis and/or experimentation to show performance advantages over current electrically powered devices.

PHASE II: Develop the novel chemically-driven light sources and characterize the output performance with detailed spectral and temporal measurements. Incorporate the technology into compact devices suitable for testing in operational scenarios.

PHASE III DUAL USE APPLICATIONS: The resulting technology will have significant carry over benefits, including enabling enhanced sensing of the environment, homeland security sensing and surveillance, and potential biomedical applications.

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KEYWORDS: Light Sources, Chemical Power, Beacons, Sensors.

SB062-020 TITLE: Sparse Array Applications for Small Satellites

TECHNOLOGY AREAS: Sensors, Space Platforms

OBJECTIVE: Identify and develop innovative system concepts for sparse array radio frequency space-based constellations utilizing small satellites.

DESCRIPTION: Small satellites because of their size are limited in the remote sensing resolution capability (i.e. aperture) of each individual satellite. Sparse array approaches using multiple small satellites offer a potential solution for the implementation of higher resolution remote sensing capabilities in space. Coherent system operation of a sparse array in the receive mode imposes precise dynamic position knowledge requirements for individual array elements, measured in fractions of a wavelength. Existing and emerging relative position measurement approaches provide potential solutions for coherent sparse array receivers when operating at radio frequencies (RF). Sparse array receiver approaches require a higher level of signal processing complexity as compared to fixed-surface monolithic RF antennas. A space-based sparse array RF receiver will have to solve both the dynamic position knowledge and multi-element receiver correlation problems in real time in order to support remote sensing RF receiver applications. Development of capabilities for satellite onboard processing in either distributed or localized modes can provide a means to minimize the data transmission requirements to earth station receivers.

PHASE I: Conduct an assessment of RF sparse array concepts with specific focus on coherent operation and onboard processing techniques. Identify candidate sparse array receiver concepts that can operate in a passive (radiometric) or bistatic mode.

PHASE II: Develop preliminary designs for candidate RF sparse array concepts identified in Phase I. Identify enabling technologies and develop ground-based and space-based demonstration efforts to establish concept viability. Utilize space-test approaches that minimize satellite mass while maximizing concept demonstration utility.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial space-based remote sensing and receiver arrays such as low earth orbit passive sensors and lightweight, large-aperture deep space communications receivers.

REFERENCES:
1. TechSat 21 – “Space Missions Using Collaborating Constellations of Satellites”, Alok Das and Richard Cobb, Air Force Research Laboratory, (AFRL/SV). 12th AIAA/USU Conference on Small Satellites, August, 1998, SSC98-VI-1
2. Sparse, Random Array Processing for Space-Based Radar, John K. Schindler, Hans Steyskal Air Force Research Laboratory Sensors Directorate (SNHA), IEEE 2004 0-7803-8281-1/04, pgs 117-121

KEYWORDS: Sparse Array, Small Satellite, Coherent Array, RF Devices, Bistatic Receiver Space-Based Antenna.

SB062-021   TITLE: Multiple Foveated Vision Sensor for Bandwidth Optimization

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Identify and develop a foveated vision sensor capable of multiple, simultaneous localized high-resolution, high frame-rate pixel-level imaging processes on a single sensor.

DESCRIPTION: As imaging sensors increase in size (pixel count) to 100+ megapixels per sensor the onboard processing and data transmission bandwidth requirements often exceed available resources, thereby imposing restrictions on sensor data rates and or image compression approaches. In most cases the entire sensor image is captured and transmitted with minimal compression to optimize image quality and information content. High frame rate (30 frames per second) imaging applications can easily exceed data rates of 300 megabits per second for uncompressed imagery generated by today’s relatively small megapixel (1K by 1K) sensors. As sensors increase in size and pixel count, the demand for data throughput will continue to outstrip available data transmission capabilities. Recent developments in active pixel sensors (APS) in a complementary metal-oxide semiconductor (CMOS) very-large-scale integrated (VLSI) circuit provide advanced features for on-chip processing of multiple, simultaneous localized regions (foveations) within a single CMOS sensor array. Such a capability could enable a single sensor array to partition its processing load by varying the resolution and frame rate within regions of the array in response to onboard cues or external commands. This could dramatically reduce the data generated per sensor image frame thereby maximizing data transmission bandwidth utilization.

PHASE I: Conduct an assessment of available imaging sensor designs and processors that could support foveated vision capabilities. Develop test scenarios and define software development required to conduct foveated processing against at least 10 targets (minimum 40 pixel total size) simultaneously at 30 Hz frame rate. Identify candidate hardware, processing approaches and relevant application scenarios. Estimate potential bandwidth reduction capabilities.

PHASE II: Develop candidate sensor, processor and image processing exploitation algorithms to conduct simultaneous foveated vision processing demonstrations for multiple objects of interest (at least 10 with minimum object size of 40 pixels) within a constant sensor field of view. Conduct foveated vision image processing demonstrations at frame rates up to and including 30 Hz. Identify processing and hardware requirements to scale the demonstration scenario capabilities to at least 100 simultaneous areas within a 100 megapixel sensor.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military imaging sensors such as airborne or building mounted sensors for urban warfare of in civilian commercial security specifically for very high resolution onboard sensors where pixel-level foveated image processing can dramatically reduce data storage and data downlink bandwidth requirements.

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KEYWORDS: Foveated Vision, Bandwidth Reduction, CMOS, Image Processing, Image Compression.

SB062-022 TITLE: Low Cost Distributed Explosive Detection Device

TECHNOLOGY AREAS: Sensors, Human Systems

OBJECTIVE: Develop a low cost explosive detection technology that can be placed in the heating ventilation and air conditioning (HVAC) systems of apartment buildings or other similar structures. This detection system should be capable of being linked through a wired or wireless system to local law enforcement.

DESCRIPTION: US forces have difficulty locating bomb factories in Iraq and Afghanistan. Many of these bomb factories are located in apartment buildings or other large dwellings. The ventilation system provides a ready access to sample the air in the apartment building for vapors outgassing from explosives. The goal of this SBIR is to develop an economical sensor that can be placed on the HVAC system that will detect the build up of a large quantity of explosives and not false alarm due to the complex mixture of chemicals in the outflow from the apartments. A number of confusers will be present at all times including household chemicals, matches, children’s cap guns, ammunition reloading, insecticides and solvents. The detection device must have the ability to distinguish between these confusers and a real threat. The system should be capable of being linked either by a standard telephone line or through a wireless connection to the Tactical Operations Center for the area. The system must be able to communicate location and some indication of magnitude of the threat.

PHASE I: Conduct feasibility study to demonstrate detection of an explosive amid a number of confusers. Show that the technology being considered can be produced economically at a large scale.

PHASE II: Build and test a prototype system which at a minimum includes the explosive detection and wired reporting technology.

PHASE III DUAL USE APPLICATIONS: This technology has applications for Homeland Security and local law enforcement in detecting illicit bomb factories or methamphetamine laboratories.

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KEYWORDS: Sensor, Explosives.

SB062-023 TITLE: 3D Visualization for Serpentine Robotic Systems

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Identify and develop an innovative sensor system to enable teleoperation or autonomous behavior of small serpentine robots.

DESCRIPTION: Teleoperation of autonomous behavior of serpentine robots requires an understanding of the macro and micro elements of local terrain, either for presentation to the operator to support remote control or to provide situation understanding to an autonomous system that is traversing the terrain. Both stereovision and optical radar (Lidar) systems have been used for this purpose in other applications, but the small diameter of serpentine systems will not provide adequate optical separation and the volume, weight and power requirements of existing lidar systems are generally incompatible with current serpentine systems under development. The challenge is to develop a system that can sense the three dimensional characteristics of the space to be traversed by the robot, in a package that will fit within a 2 inch square, 4 inches long.

PHASE I: Conduct a feasibility study on the development of techniques for the creation of a 3D representation of local terrain using a sensor system on the nose or tail of a moving serpentine system. Develop plans for the construction of the most viable system.

PHASE II: Demonstrate a proof-of-concept system that can be deployed in a serpentine system. The Government intends to make a serpentine robot available for installation and demonstration of the performance of this proof-of concept system.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian robotic systems for battle damage estimation and intelligence collection as well as search and rescue applications.

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KEYWORDS: 3D, Sensors, Manufacturing