DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
FY2008.2 SBIR Proposal Submission

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 fiscal year (FY) 2008 SBIR solicitation (FY2008.2). Please note that these topics are UNCLASSIFIED and only UNCLASSIFIED proposals will be entertained. Although they are unclassified, the subject matter may be considered to be a "critical technology" and may be subject to ITAR restrictions. If you plan to employ NON-U.S. Citizens in the performance of a DARPA SBIR contract, please inform the Contracting Officer who is negotiating your contract. These are the only topics for which proposals will be accepted at this time. A list of the topics currently eligible for proposal submission is included followed by full topic descriptions. The topics originated from DARPA technical program managers.

ALL PROPOSAL SUBMISSIONS TO DARPA MUST BE SUBMITTED ELECTRONICALLY THRU WWW.DODSBIR.NET.

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, **ENTIRE** Technical Proposal with any appendices, Cost Proposal, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR website at http://www.dodsbir.net/submission. Each of these documents is to be submitted separately through the website. Your complete proposal **must** be submitted via the submissions site on or before the **6:00am EST, 18 June 2008 deadline.** If you have any questions or problems with electronic submission, contact the DoD SBIR Help Desk at 1-866-724-7457 (8am to 5pm EST).

Acceptable Format for On-Line Submission: All technical proposal files must be in Portable Document Format (PDF) for evaluation purposes. The Technical Proposal should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Cost Proposal information should be provided by completing the on-line Cost Proposal form. This itemized listing should be placed as the last page(s) of the Technical Proposal Upload. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Proposal and the additional cost proposal information.)

Technical Proposals should conform to the limitations on margins and number of pages specified in the front section of this DoD solicitation. However, your cost proposal will only count as one page and your Cover Sheet will only count as two, no matter how they print out after being converted. Most proposals will be printed out on black and white printers so make sure all graphics are distinguishable in black and white. It is strongly encouraged that you perform a virus check on each submission to avoid complications or delays in submitting your Technical Proposal. To verify that your proposal has been received, click on the "Check Upload" icon to view your proposal. Typically, your proposal will be uploaded within the hour. However, if your proposal does not appear after an hour, please contact the DoD Help Desk.

DARPA recommends that you complete your submission early, as computer traffic gets heavy near the solicitation closing and slows down the system**.** DARPA will not be responsible for proposals being denied due to servers being "down" or inaccessible. Please assure that your e-mail address listed in your proposal is current and accurate. By the end of May, you will receive an e-mail acknowledging receipt of your proposal.

PLEASE DO NOT ENCRYPT OR PASSWORD PROTECT 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.

Additional DARPA requirements:

- DARPA Phase I awards will be Firm Fixed Price contracts.
- **If you collaborate with a University, please highlight the research that they are doing and verify that the work is FUNDAMENTAL RESEARCH.**
- Phase I proposals **shall not exceed $99,000,** and are generally 6 months in duration. Phase I contracts cannot be extended.
- DARPA Phase II proposals must be invited by the respective Phase I DARPA Program Manager. Phase 2 invitations will be based on the technical results reflected in the Phase I contract and/or final reports 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.

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: http://www.ccr.gov.

The responsibility for implementing DARPA's Small Business Innovation Research (SBIR) Program rests with the Contracts Management Office.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Attention: DIRO/SBIR/STTR
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 526-4170
Home Page http://www.darpa.mil

SBIR proposals submitted to DARPA will be processed by DARPA and distributed to the appropriate technical office 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, technical merit, and innovation of the proposed approach and its incremental progress toward topic or subtopic solution" (refer to section 4.2 Evaluation Criteria - Phase I - page 7), twice the weight of the other two evaluation criteria. PLEASE NOTE THAT MANY OF THE WEAKEST PROPOSALS SCORED LOW ON EVALUATION CRITERIA "C" "THE POTENTIAL FOR COMMERCIAL (GOVERNMENT OR PRIVATE SECTOR) APPLICATION AND THE BENEFITS EXPECTED TO ACCRUE FROM THIS COMMERCIALIZATION. DARPA IS PARTICULARLY INTERESTED IN THE POTENTIAL TRANSITION OF SBIR RESULTS TO THE U.S. MILITARY, AND EXPECTS EXPLICIT TREATMENT OF A TRANSITION VISION IN THE COMMERCIALIZATION-STRATEGY PART OF THE PROPOSAL. THAT VISION SHOULD INCLUDE IDENTIFICATION OF THE PROBLEM OR NEED IN THE DEPARTMENT OF DEFENSE THAT THE SBIR RESULTS WOULD ADDRESS, A DESCRIPTION OF HOW WIDE-SPREAD AND SIGNIFICANT THE PROBLEM OR NEED IS, AND IDENTIFICATION OF THE POTENTIAL END-USERS (ARMY, NAVY, AF, SOCOM, ETC) WHO WOULD LIKELY USE THE RESULTS. THE SMALL BUSINESS MUST DEMONSTRATE UNDERSTANDING OF THE END USE OF THEIR EFFORT AND THE END USERS.

ALL SELECTION/NON-SELECTION LETTERS WILL BE SENT TO THE PERSON LISTED AS THE "CORPORATE OFFICIAL" ON THE PROPOSAL.

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.

DARPA SBIR 082 Topic Index

SB082-051 Efficient Small Antennas
SB082-052 Indium Gallium Nitride (InGaN) Solar Cell
SB082-053 Low-Cost Device Relevant Indium Gallium Nitride (InGaN) or Alternatives
SB082-054 Explosion-Proof Solid State Lighting Fixture for Extreme Environments
SB082-055 A Spectrally Dynamic Berth Light for Active Circadian Cycle Management
SB082-056 Mobile Offshore Platform for Wind Turbine Power Generation
SB082-057 Non-Line-of-Sight Ultraviolet (UV) Communication Networks
SB082-058 Mission Assured Networking (MAN)
SB082-059 Continuous Detonation Rocket and Air Breathing Engines
SB082-060 Wireless Avionics Architecture for Payload Delivery Launch Systems
SB082-061 Transformational Close Air Support
SB082-062 Leap-Ahead Control Theoretic Applications
SB082-063 Energy Rejection Systems for Very High Altitude Aircraft
SB082-064 Metal Hydride Energy Sources for Very High Altitude Aircraft Propulsion

DARPA SBIR 082 Topic Descriptions

SB082-001 TITLE: Nonlinear Plasmonic Devices

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Full integration of electronics and photonics on a single chip has been frustrated by the huge differences in device sizes. While electronic miniaturization has proceeded rapidly to record breaking transistor sizes of only 35 nm, photonic waveguides and devices have been limited to sizes of a few optical wavelengths ~3,000 nm. For applications in integrated circuits, the comparatively huge dimensions of photonic devices relative to electronic devices have prohibited the valuable use of the large bandwidths associated with photonics. Recently, the field of plasmonics has emerged as a likely candidate to provide photonic waveguides and devices with the sizes comparable to electronic circuits. Plasmonic waveguides have been under development for several years but the technology for plasmonic devices is lacking. The objective of the Phase I is to perform a feasibility study of a nonlinear plasmonic device with dimensions much smaller than current photonic devices.

DESCRIPTION: The huge information carrying capacity of optical fiber networks is a result of the high frequency of an optical electromagnetic wave. Unfortunately, the wavelength of the electromagnetic radiation used in fiber networks, and consequently the photonic device size, is approximately one hundred times larger than typical electronic components. Increasing the electromagnetic frequency to reduce the wavelength would lead to the need for X-ray waveguides, sources, and switches. The other approach is to stay at optical frequencies but use high index dielectrics to shrink the wavelength by a factor proportional to the index of refraction. Unfortunately the latter approach can only provide a wavelength reduction of five or less.

A surface plasmon is a collective oscillation of electrons at the surface of a metal[1]. These surface waves oscillate at optical frequencies and propagate along the surface of the metal. The wavelength of a surface plasmon can be very small and comparable to the dimensions of electronic circuits. In addition, the plasmons are tightly confined to the surface with transverse decay lengths on the order of the skin depth, 10 nm. Plasmonic waveguides[2], while lossy compared with optical fibers, only need to carry information several centimeters across a chip. Thus, plasmonics is expected to be the bridge that links electronics with photonics[3-5].

It has recently been proposed that electromagnetic radiation at optical frequencies can be focused to a spot size of only 5 nm through the use of surface plasmons[6]. This extremely tight confinement of electromagnetic waves provides opportunities to fabricate photonic devices with sizes comparable to state of the art electronic devices. In accompaniment with the small volume will be large field strengths and high intensities but at very low energies. These are the ideal conditions for third order nonlinear optical devices that will have very low switching threshold energies and fast response times. Second order nonlinear optical devices for harmonic generation, etc., will also benefit from the features inherent in plasmonic devices. As seen in a recent survey of plasmonics in Ref. 7, almost no work has been done in the area of plasmonic devices. The purpose of this task is to stimulate research in the area of second and third order nonlinear optical devices based on plasmonics.

PHASE I: Conduct a feasibility analysis of a nonlinear plasmonic device with size dimensions compatible with electronic circuitry. Suggested devices include, but are not limited to, all-optical switch, optical limiter, frequency up-conversion, frequency down-conversion, self focusing, self phase modulation, and Raman scattering.

PHASE II: Finalize the device and material parameters from the Phase I. Conduct basic experimental observation of the expected performance of the plasmonic device. Design and fabricate a prototype, ultra-compact plasmonic device.

PHASE III: Possible applications for this technology span both the military and commercial arenas. The rapid increase in the clock speed of computers has slowed in recent years due to the interconnect bottlenecks on the chip itself. A plasmonic architecture is expected to alleviate the problems associated with the large size of present day optical components. In the near term, for applications not requiring an entire plasmonic ensemble of waveguides, sources, detectors, and devices, individual advances in plasmonic devices will help to couple photonics to the rapidly developing field of nanotechnology.

REFERENCES:
1. R.H. Ritchie, Plasma Losses by Fast Electrons in Thin Films, Physical Review 106, 874 (1957).

2. J.A. Dionne, L.A. Sweatlock, H.A. Atwater, and A. Polman, Plasmon slot waveguides: Towards chip-scale propagation with subwavelength-scale localization, Phys. Rev. B 73, 035407 (2006).

3. Harry A. Atwater, Stefan Maier, Albert Polman, Jennifer A. Dionne, and Luke Sweatlock, The New "p–n Junction": Plasmonics Enables Photonic Access to the Nanoworld, Materials Research Society Bulletin 30, 385 (2005).

4. Rashid Zia, Jon A. Schuller and Mark L. Brongersma, Plasmonics: The Next Chip-Scale Technology, Materials Today 9, 20 (2006).

5. S. A. Maier, M. L. Brongersma, P. G. Kik, S. Meltzer, A. A. G. Requicha, H. A. Atwater, Plasmonics - A Route to Nanoscale Optical Devices, Advanced Materials 13, 1501 (2001).

6. J. Conway, S. Vedantam, H. Lee, J. Tang, and E. Yablonovitch, What is the Smallest Volume Into Which Light Can Be Focused, Efficiently?, International Nano-Optoelectronics Workshop, i-NOW'07, p. 77 (2007).

7. E. Ozbay, Plasmonics: Merging Photonics and Electronics at Nanoscale Dimensions, Science 311, 189 (2006).

KEYWORDS: Plasmonics, Surface Plasmon, Plasmon Waveguides, Thin Films

SB082-002 TITLE: Autonomous Detection, Acquisition, Pointing, and Tracking of Small UAVs

TECHNOLOGY AREAS: Ground/Sea Vehicles, Sensors, Electronics, Weapons

ACQUISITION PROGRAM: N/A

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 effort is to provide the capability to autonomously detect, acquire, declare, point, and track on small scale UAVs to range of 1 kilometer and altitude of 500 meters. The system will control a telescope with a Coude path that allows integration of a high power laser to neutralize the sensors and/or airframe.

DESCRIPTION: The use of Unmanned Aerial Vehicles (UAVs) in both Military and Civilian markets has skyrocketed in the last 3-5 years. On the battlefield, the commanders have unprecedented capability to perform Intelligence, Surveillance, and Reconnaissance (ISR) missions. UAVs are also evolving into lethal platforms1, further enhancing the Army's ability to See First, Understand First, Act First, and Finish Decisively. Unfortunately, with the emergence of low-cost, hobbyist type aircraft with the capability to carry visible and Infrared (IR) cameras and to fly on Global Positioning System (GPS) waypoints, our adversary is rapidly encroaching on our ability to "See First". Also, the utility of these small UAVs for terrorist activities in the civilian sector are endless2.

The use of RADARs to search an area for small UAVs have had limited success. This is due to the low Radar Cross Section (RCS) of the composite structures typically employed on these vehicles. This effort is intended to focus on the use of novel methods including, but not limited to, acoustical, Electro-Optical-Infrared (EO-IR), and polarimetry to search and monitor the civilian and military airspace. Both active and passive techniques will be considered.

PHASE I: Prepare a feasibility study that provides the framework to detect, acquire, declare, point, and track on a small UAV. For the purposes of this effort, a small scale UAV is defined as having a wingspan of less than 1 meter, a range of 1 kilometer (or better), and an operational altitude of 500 meters. The UAV structure may be constructed of foam or composite material and the propulsion system may be electric or fossil fuel. During Phase I, the performer will propose techniques for detecting and acquiring the position of the UAV and subsequent handoff to an optical pointing and tracking subsystem. The design of the optical pointing and tracking subsystem shall include a Coude path allowing the integration of a high power (~2kW) laser. Formal design of the concept will be performed, a preliminary design review conducted, and the final report generated. As part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized. The detection hardware and software will be developed and integrated into the pointing and tracking optical subsystem. The pointing and tracking optical subsystem shall have the following minimum requirements:
1) Velocity (Az) > 80 deg/sec, Velocity (El) > 50 deg/sec.
2) Acceleration (Az) > 80deg/sec2, Acceleration (El) > 50 deg/sec2.
3) Maintain tracking accuracy to less than 50 microradians.

A critical design review will be performed to finalize the design and a breadboard system will be assembled. The system will be subjected to a series of qualification tests to verify and validate the design and its performance. Finally, the system will be delivered to the Weapons Sciences Directorate, AMRDEC, Redstone Arsenal, AL.

PHASE III DUAL USE APPLICATIONS: Military applications of this effort include Counter-Intelligence, Surveillance, and Reconnaissance (C-ISR) and Counter Airborne Improvised Explosive Device (C-AIED) missions. There are also several commercial applications of this technology that address possible counter-terrorist threat activities in the civilian sector.

REFERENCES:
1. Osborn, K., Army Records First UAV Kills, Army Times, 17 Sept 2007.

2. Miasnikov, E., Threat of Terrorism Using Unmanned Aerial Vehicles, Center for Arms Control, Energy, and Environmental Studies, 2005.

KEYWORDS: UAV, CUAV, Airborne IED, Pointing, Tracking, High Energy Laser

SB082-003 TITLE: Mode-Locked TEA CO2 Laser

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes, Sensors, Battlespace, Weapons

ACQUISITION PROGRAM: N/A

OBJECTIVE: Perform a feasibility study to develop (Phase I) and construct (Phase II) a powerful mode-locked, transverse excitation atmospheric (TEA) carbon dioxide (CO2) laser. The laser should produce pulses shorter than 100 ps, tunable over the 9-11 micron wavelength region, preferably with peak fluence in excess of 10 mJ per pulse.

DESCRIPTION: Stand off spectroscopic detection of chemical agents and explosives has been accomplished using a variety of techniques, including LIDAR, Fourier-transform infrared (FTIR) spectroscopy, and most recently terahertz (THz) spectroscopy. THz spectroscopy of molecular rotational levels provides superior specificity for the identification of many gas-phase analytes, but THz systems have not been fielded widely because of a combination of challenges including poor THz sources and obfuscating atmospheric effects. THz sources in the 0.1-1.0 THz region, though comparatively weak, have matured dramatically in recent years and are now commercially available. Atmospheric line broadening, attenuation, and fluctuations, however, remain as hurdles.

Recently, a new methodology for performing stand-off agent detection has been proposed.[1] This technique overcomes the inherent limitations of atmospheric THz attenuation by exciting the agent cloud with a high power, mode-locked TEA CO2 laser.[2] The technique overcomes the limitations of line broadening because the laser pulses induce a brief terahertz transient absorption or emission, unique to the analyte interrogated, which may be observed with a THz transceiver. The CO_2 laser is relatively unattenuated by the atmosphere, dramatically lowering the THz power requirements for the THz transceiver. Significantly, the collisional relaxation of rotational states at atmospheric pressures occurs on time scales faster than 100 ps, requiring the laser to produce intense pulses (>10 mJ/pulse) at least that fast.

PHASE I: Prepare a feasibility study demonstrating how a powerful (preferably >10 mJ/pulse), wavelength tunable (9-11 microns), mode-locked TEA CO_2 laser would be constructed and tested. In the proposal, the performer will outline key attributes of the conceptual laser and identify key research obstacles to be addressed in Phase I. During Phase I, formal design of the concept will be performed, and a preliminary design review and report will be generated, specifically including performance and noise estimates. Experimental work to remove key obstacles is not required for Phase I but may be undertaken at the proposer's discretion. As part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized. All appropriate engineering testing and validation of design issues will be performed. A critical design review will be performed to finalize the design, and a prototype unit meeting the specifications will be manufactured and tested. By the end of Phase II, the working laser must be thoroughly characterized, quantifying both performance and noise over the design space. The laser and all related hardware (e.g. power supplies and electronic control) will be delivered to the Army Aviation and Missile RDEC, located at Redstone Arsenal, AL, for extensive test and evaluation.

PHASE III: Perhaps the most likely application of a mode-locked CO_2 laser is in atmospheric monitoring of the distribution of trace gases. Of particular interest is the analysis of trace gases emitted from smokestacks, factories, and other fixed facilities that need to be monitored at a distance for long durations. A secondary application will be the study of laser-induced effects on surfaces and materials. There is potential military application of this laser for infrared targeting and countermeasures.

REFERENCES:
1. F.C. De Lucia, D.T. Petkie, and H.O. Everitt, "A double resonance approach to submillimeter/terahertz remote sensing at atmospheric pressure," Chemical Physics 0710.5887, (2007) and references therein, especially references 17-21.

2. H. Houtman and J. Meyer, "Ultrashort CO_2 laser pulse generation by square-wave mode locking and cavity dumping," Optics Letters Vol. 12, p. 87 (1987).

3. D.G. Youmans, F. Corbett, G. Dryden, and M. Kovacs, "Theoretical and Monte Carlo analyses of the range-Doppler imaging capabilities of mode-locked CO_2 ladars," SPIE Vol. 2702 (0-8194-2076-X), p. 40 (1996) and references therein.

KEYWORDS: Infrared Laser, Modelocked Laser, Molecular Spectroscopy, Double Resonance

SB082-004 TITLE: Femtosecond UV Laser Pulse Expander

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes, Sensors, Weapons

ACQUISITION PROGRAM: N/A

OBJECTIVE: Perform a feasibility study to develop (Phase I) and construct (Phase II) an external laser pulse expander for femtosecond pulses in the ultraviolet (UV)-blue spectral range (minimally 350-450 nm). The expander must be capable of expanding input pulses of 100 fs width to any user-specified pulse width up to at least 1 ns. The design should accommodate input laser pulses with repetition rates 1 kHz – 80 MHz and input fluences as high as 100 microjoules.

DESCRIPTION: Military interest in the ultraviolet portion of the spectrum comes in two forms: as a unique spectral window for sensing targets, and for spectroscopic identification of trace amounts of explosives, chem/bio agents, and toxic chemicals. In both applications, development of more powerful laser sources (and increasingly sensitive detectors) has been required for practical fieldable systems to be contemplated. Femtosecond laser pulses are commonly generated at UV wavelengths by frequency-converting near infrared (IR) femtosecond pulses from Ti:sapphire lasers using nonlinear optical techniques. The pulse width of a UV laser beam generated in this fashion is comparable to that of the original near IR beam (~100 fs). However, because different chemical and biological processes occur on various sub-nanosecond time scales, it is of interest to probe these systems with laser pulses of adjustable width. Variation of laser pulse width also allows for very predictable changes in peak power delivered to targets such as sensor arrays.

Femtosecond pulses are routinely expanded to several tens or hundreds picoseconds for the purpose of chirped pulse amplification; however, in addition to being chirped, the pulses exit such pulse stretchers with very specific pulse widths suitable for specific types of amplification. More flexibility is afforded by dispersion-free pulse shaping schemes wherein a femtosecond pulse of arbitrary shape can be generated using gratings in conjunction with lithographic masks [1], liquid crystal modulators [2-3], acousto-optic modulators [4], and deformable mirrors [5]. Pulse shapers have historically been used primarily to create novel pulses and pulse trains still characterized by sub-picosecond pulse widths, whereas the interest here is keeping the pulse shape simple (for example, square) but adjusting the pulse width over several orders of magnitude.

To address potential military applications in the ultraviolet, the pulse expander should at least span the tuning range of a (customer provided) frequency doubled Ti:Sapphire laser (350-450 nm), and preference will be given to solutions that go farther into the UV. The primary requirement of the expander will be to generate a stable, minimally chirped output pulse of adjustable width from 100 fs to at least 1 ns. The expander should be able to accommodate UV pulse fluences from nJ to ~100 uJ energy. Attention should be paid to minimizing the insertion and operational loss of the pulse expander (e.g. by modulating the phase rather than the amplitude of the spectrally dispersed pulse) while minimizing induced pulse-to-pulse width and amplitude variability so that pulse fluence and stability is maintained as much as possible from input through the expander. Finally, the qualitative temporal shape of the pulse should remain approximately square over the pulse width tuning range. Solutions that permit the generation of other user-specified pulse shapes or chirp are welcomed but not required.

PHASE I: Prepare a feasibility study demonstrating how a femtosecond UV pulse expander would be constructed and tested. In the proposal, the performer will outline key attributes of the conceptual expander and identify key research obstacles to be addressed in phase I. During phase I, formal design of the concept will be performed, and a preliminary design review and report will be generated, specifically including performance estimates. Experimental work to remove key obstacles is not required for Phase I but may be undertaken at the proposer’s discretion. As part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized. All appropriate engineering testing and validation of design issues will be performed. A critical design review will be performed to finalize the design, and a prototype unit meeting the Phase I specifications will be assembled and tested. By the end of Phase II, the working pulse expander must be thoroughly characterized for performance and noise. The expander and all related hardware and software (excluding test laser[s]) will be delivered to the Army Aviation and Missile RDEC, located at Redstone Arsenal, AL, for further testing and evaluation.

PHASE III: Related commercial applications of an adjustable pulse width, sub-nanosecond UV laser include spectroscopic tools tailored to investigations of novel UV materials and phenomena, particularly wide band gap semiconductors, organic/inorganic hybrid materials, and plasmonics. Also of commercial interest is the analysis of trace gases emitted from smokestacks, factories, and other fixed facilities that need to be monitored at a distance for long durations. A third application could be the study of laser-induced effects on surfaces and materials. Because many chem/bio agents absorb UV light, a potential military application is the optical detection and/or identification of such agents. Other potential military applications of this modulated laser include UV targeting and countermeasures.

REFERENCES:
1. Weiner, A.M., Heritage, J.P., and Kirschner, E.M., "High-resolution Femtosecond Pulse Shaping," J. Opt. Soc. Am. B, Vol. 5, No. 8, pp. 1563-1572, 1988.

2. Weiner, A.M., "Femtosecond Pulse Shaping Using Spatial Light Modulators," Rev. Sci. Instrum., Vol. 71, No. 5,

pp. 1929-1960, 2000.

3. Zheng, Z., Leaird, D.E., et al., " 20-fs Pulse Shaping with a 512-Element Phase-Only Liquid Crystal Modulator," IEEE J. Sel. Top. Quantum Electron., Vol. 7, No. 4, pp. 718-727, 2001.

4. Fetterman, M.R., Goswami, D., et al., "Ultrafast Pulse Shaping: Amplification and Characterization," Opt. Express, Vol. 3, No. 10, pp. 366-375, 1998.

5. Garduno-Mejia, J., Greenaway, A.H., and Reid, D.T., "Programmable Spectral Phase Control of Femtosecond Pulses by Use of Adaptive Optics and Real-time Pulse Measurement," J. Opt. Soc. Am. B, Vol. 21, No. 4, pp. 833-843, 2004.

KEYWORDS: Optical Modulator, Pulse Expander, Ultraviolet Laser, Ultrafast Laser, Agent Detection

SB082-005 TITLE: Low Cost Radar Receivers

TECHNOLOGY AREAS: Materials/Processes, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop low cost radar receivers and processing techniques for manufacturing integrated cooling capability which is ruggedized to meet military requirements.

DESCRIPTION: Current microwave and millimeter wavelength radar systems use high cost materials and hence have suboptimal packaging, have a relatively high parts count, and have quite limited degree of parts standardization. There is a need to reduce the cost of receivers to achieve low cost radars.

It is known that improved radar receiver cost and performance can be achieved by reducing or eliminating high cost materials and processing, reducing parts count, standardizing parts, and integrating packaging. Potential means of reducing high cost materials and their associated processing are cooling the receiver and achieving high density packaging. The degree of cooling and cooling mechanisms has not been extensively studied to date. There are cost and performance tradeoffs in terms of cooling and packaging to be determined prior to implementation. A low cost radar receiver technology seeking to lower the cost of components such as the low noise amplifier, mixer and interconnects in conjunction with improved packaging and testing is desired for potential radar applications.

PHASE I: Feasibility Study to identify the potential for low cost receivers to achieve near or equivalent performance with current receivers for X, Ku, and Ka band. Identify cost and performance matrix for receivers based on such options as packaging, parts count, standardization and cooling. Identify various technologies and materials and provide current status of how these can meet DoD aviation and missile requirements including extreme environments. List any shortfalls as areas for further research. Develop a list of materials, manufacturing and process technology needed to make system capable of meeting aviation and missile requirements. Consider technology which will enhance commercially available technology for this use. Material considerations should include performance, corrosion, environmental, cost, and processing hazards. System configuration should be easily assembled and use readily available materials to the greatest extent possible. Hardware of interest includes the Low Noise Amplifier, mixer and interconnects.

PHASE II: Fabricate a bench top receiver to demonstrate proof of principle. Investigate methods of achieving low cost and system requirements. Create a cost, performance, and issues matrix to determine challenges for the prototype materials, processing, and integration techniques. Develop technology and fabrication processes to meet military aviation and missile requirements for an X band receiver. This should be performed in concert with the government as a result of the best alternative from PHASE I. Consider system requirements to include environmental such as temperature extremes from operation and storage, and shock and vibration induced environments. Design approaches needed to provide adequate performance while not adding significantly to receiver size, weight, power requirements, and cost. Based on information acquired from iterations in design, fabrication, and testing, down select design, materials, and processes deemed to have the most promise with sufficient maturity, at a reasonable cost to allow development of a stable prototype design and process by the end of Phase II. Electronic and thermal performance, material costs, processing costs, and expected yields should be considered in the down select. Demonstrate a low cost receiver operation during a physically simulated takeoff of an aircraft or missile. Performance and structural integrity required to maintain performance during the mission needs to be achieved. Perform bench test following the test with a simulated shock to further verify performance. Physically inspect the receiver and associated hardware. Note any changes from pretest physical configuration. Some physical changes may be permissible but only to the extent that performance is not degraded. Refine the initial design of receiver and associated manufacturing processes and develop low cost methods for testing the receiver unit. Investigate potential applications for tactical missiles and short range Unmanned Aerial Vehicles (UAVs.) Note and recommend system and processing changes which could be used to expand applicability to longer mission systems.

Develop a draft business plan showing potential commercial and military applications and production/product costs and schedule for implementation in medium and high volumes.

PHASE III: Candidate applications for this technology span both the military and commercial arenas. In general terms, the linearized analog photonic link components to be developed will be used in avionics, communication, radar/telemetry, electronic warfare, WiFi, CATV, instrumentation and other commercial and DoD transmission and signal processing applications. Some specific military uses include high bandwidth, multi-wavelength, fiber-optic signal transmission systems as well as optical time delay modules for broadband signal processing and phased-array antenna applications. Wideband electronic warfare receivers are another prime military insertion point for this technology. On the commercial side, radio frequency receivers are used in a wide variety of products and thus this technology could provide for significant commercial market impact.

REFERENCES:
1. Lucas, Michael R., Turley, Alfred P., Marcelli, Carmine, Adil, Farhan, Montano, Sergio, Suko, Scott, and Fudem, Howard, Office of Naval Research Report, Mixed-Signal SiGe Radar-on-a-Chip, 20 March 2006.

2. Zampardi, Pete, SiRf 2007 Conference paper, Performance and Modeling of Si and SiGe for Power Amplifiers, Jan 2007.

KEYWORDS: Low Cost Microwave Receiver, Low Cost Millimeter Wavelength Receiver, Silicon Germanium, Gallium Arsenide

SB082-006 TITLE: Ultra Lightweight, Low Power Thermal Camera for Micro-Platforms

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: N/A

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 the Phase I effort is to develop technologies for extremely lightweight, low power thermal micro-cameras for use on micro-vehicles. Proposed research should investigate and exploit innovative approaches that will enable revolutionary advances in lightweight, low power infrared (IR) cameras.

DESCRIPTION: The increasing number of applications for small platforms in military operations has led to an emphasis on nighttime imaging payloads, compatible with micro-platforms. Similarly, the increased demands placed on the individual warfighter for situational awareness, require high performance, lightweight thermal imaging systems. Current Concept of Operations is driving the military to utilize remote sensing assets such as micro-air vehicles, robots, and distributed sensors systems. These platforms suffer from limited payload capability – weight, size, and power. With these constraints in mind, a new generation of imagers are needed that will provide the warfighter with “over the hill” and “around the corner” surveillance needed for nighttime dominance.

To meet the applications described above, a thermal camera having a weight less than 15 grams and power consumption less than 200 mW is desired. The total camera weight includes optics, packaged detector, and electronics. The sensor field of regard should be forty (40) degrees. Ultimate system performance should be recognition of a one (1) meter target at one-hundred (100) meter range with a high probability of detection, and detection of low contrast targets with a delta temperature relative to the background of 1 degree C. Unique signal processing may be implemented on the platform to reduce data rates, extract significant information, and enhance image quality. Pixel level data could be sent to a remote ground station for processing to reduce the burden on the on-board electronics, however, bandwidth limitations need to be considered and download data rates need to be compatible with standard video transmission formats. A trade study should be conducted comparing processing on the platform versus processing at a collection site.

PHASE I: Develop overall thermal camera system design that addresses size, weight and power. Proposed designs must describe any revolutionary advances in technology needed to meet the thermal camera goals. Any advances in materials, detectors, focal plane arrays, micro-packaging, optics, electronics and signal processing that enable the development of an extremely lightweight, low power IR camera must be completely explained. Current limitations with existing technologies must be addressed. As part of the final report, plans for Phase II will be proposed.

PHASE II: Prototype Phase I design to demonstrate and validate new thermal camera concept. The prototype must demonstrate the capability to achieve the desired final system design goals – total weight less than 15 grams, system power consumption less than 200mW, field of regard of forty degrees, recognition of a one (1) meter target at one-hundred (100) meter, and detection of low contrast targets with a delta temperature relative to the background of 1 degree C.

PHASE III: The technology developed under this SBIR can be used in military and civilian IR cameras. Thermal imagers are being integrated into automobiles for collision avoidance, home and business surveillance systems, and being used by law enforcement and firefighters.

REFERENCES:
1. Kostishack, D.F., Micro Air Vehicles for Optical Surveillance, The Lincoln Laboratory Journal, Number 2, 1996.

2. Michelson, R.C., Update on Flapping Wing Micro Air Vehicles Research, 13th Bristol International RPV Conference, Bristol England, 30 March - 1 April 1998.

3. Brady, D.J., Compressive Imaging Sensors, Proceedings of SPIE. Vol. SPIE-6232, pp. 43-51. (2006).

4. McMichael, J. M., Micro Air Vehicles - Toward a New Dimension in Flight, DARPA, USA. 1997.

5. Bohorquez, F., Design and Development of a Biomimetic Device for Micro Air Vehicles, Proc. SPIE Vol. 4701, p. 503-517, Smart Structures and Materials 2002.

6. http://www.darpa.mil/dso/thrusts/materials/multfunmat/wasp/index.htm

KEYWORDS: Micro Air Vehicles, Thermal Imaging, Thermal Sensors, Light Weight IR Camera

SB082-007 TITLE: Advanced Development for Defense Science and Technology

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: Identify and develop innovative technology in the Physical, Engineering, and Life Sciences for enabling defense technology.

DESCRIPTION: Novel technology which relies on innovations in science and engineering has provided a critical advantage to our national defense. To this end, DSO is soliciting proposals for advanced technology development in a variety of enabling technical areas which include:
- Application and development of advanced mathematics for DoD applications.
- New and innovative approaches to biosensor technology and biological technology for maintaining the warfighters performance, capabilities and survival in battlefield conditions.
- Remote interrogation and control of biological systems at the system/organ/tissue/cellular/molecular scales and new technologies to drastically reduce the logistics burden of medical treatment in the field.
- Novel interface and sensor designs for interacting with the central (cortical and subcortical structures) and peripheral nervous systems, with a particular emphasis on non-invasive and/or non-contact approaches.
- New dual-use processes and materials that translate biomolecular mechanisms to innovative, highly advantages new routes for material and device systems.
- New materials and processes that provide revolutionary capability to DoD platforms and weapon systems.
- New tools to predict the performance of complex systems across a variety of domains (e.g., materials, physics, biology, etc.).
- New technology for training individuals and teams, including embedded training and simulation; technologies which lead to understanding and improving team performance; and new approaches to improve rapid decision-making in chaotic or data-poor environments.

PHASE I: Conduct a feasibility study which would investigate and define the proposed idea or device and its feasibility.

PHASE II: Develop the research and technology advances and methods identified in Phase I to demonstrate a proof-of-concept prototype.

PHASE III: The technology developed under this SBIR will be used in both the military and civilian commercial sector.

REFERENCES:
1. "Director, Defense Research & Engineering Home Page," Department of Defense. http://www.dod.mil/ddre/mainpage.htm

2. "DDR&E Science & Technology Home Page," Department of Defense. http://www.dod.mil/ddre/scitech.htm

3. "Office of Science and Technology Policy," Executive Office of the President. http://ostp.gov/

KEYWORDS: Sensor Array, Biotechnology, Novel Materials, Embedded Training, Decision Making,

SB082-008 TITLE: Integrated Structural Insulation to Eliminate Multi-Layer Insulation for Satellites

TECHNOLOGY AREAS: Space Platforms

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop and validate alternative integrated structural insulation concepts to eliminate the need for multi-layer insulation for spacecraft systems.

DESCRIPTION: Multi-Layer Insulation (MLI) is the most common thermal control technology used on spacecraft. The reason for this is its outstanding thermal properties. Traditionally, MLI is a complex system incorporating up to 30 layers of alternating low conductivity and low emissivity materials. Because of the alternating layers, the performance of MLI is outstanding with an effective emissivity on the order of 0.015 to 0.030. However, because of the multiple low conductivity layers it has virtually no compression strength and is fragile. In addition, it is complex to design, requires hours of touch labor to fabricate and install, and is difficult to quantify its performance. To design, fabricate, and install MLI on a small complex component can exceed two months. As a result, MLI is expensive, difficult to work with, and a major contributor to satellite development time. A significant improvement is needed in satellite insulation materials and surface treatments. Eliminating the need for MLI or integrating the insulating function into satellite structural panels would provide significant advantages for all military satellite systems including responsive satellites.

PHASE I: Explore revolutionary materials and designs based on prototypical requirements. Perform sufficient design analysis and/or physical testing to verify feasibility of proposed solution relative to typical satellite system requirements. Validation of feasibility shall be demonstrated to a level satisfactory to indicate the practicality of the design in meeting requirements and objectives.

PHASE II: Demonstrate the technology identified in Phase I. Tasks shall include, but are not limited to, a detailed demonstration of key technical parameters that can be accomplished and a detailed performance analysis of the technology. A subscale demo is acceptable, but a full-scale demo is encouraged. Also, model validation testing, a detailed evaluation report, and recommendations are required.

PHASE III: Candidate applications for this technology span both the military and commercial spacecraft arenas, since nearly all satellites currently use MLI. Of particular benefits will be commercial and military satellites that are being designed to rapidly respond to emerging changes in space operations as a result of reduced design times and the ability to provide potentially generic thermal solutions to a multitude of satellite applications. While the primary use is anticipated to be limited to military and commercial satellites, the continued growth of, and reliance on, space assets assures that sufficient market demand will accompany any potential technological breakthroughs.

REFERENCES:
1. Gilmore, David G., Spacecraft Thermal Control Handbook Volume I: Fundamental Technologies, 2nd Ed, The Aerospace Press, El Segundo, CA, 2002.

2. Jilla, Cyrus D. and Dr. David W. Miller, “Satellite Design: Past, Present, and Future,” International Journal of Small Satellite Engineering, 12 Feb 1997.

KEYWORDS: Multi-Layer Insulation, Insulation, Thermal Management, Spacecraft, Responsive Space

SB082-009 TITLE: <u>Reconfigurable Thermal Networks (RTN)</u>

TECHNOLOGY AREAS: Space Platforms

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop and validate a reconfigurable thermal network that provides on-the-fly reconfigurability for space missions.

DESCRIPTION: The traditional approach to satellite design is a customized and highly optimized satellite bus. The primary design driver is to minimize mass but often at the expense of time and money. This design driver is maintained throughout the design of the entire spacecraft. A secondary design driver is system reliability. Since spacecrafts are expensive, complex, and nearly impossible to repair once on orbit, system reliability is also important. As a result of these two constraints, every aspect of the system’s design must be carefully considered, analyzed, and tested. The results are a specialized point design for each mission and a long and arduous design process.

Currently, the design, integration, and testing of the thermal control system (TCS) requires years to complete and is a leading contributor to satellite development time. The design time for an average small satellite is one to three years. Due to the long design cycle time and the rapid evolution of technology, satellites are obsolete before they are even launched. For these reasons, technologies that will significantly reduce design time by taking advantages of advances in microelectronics, MEMS, adaptive control theory, plug-and-play electronics, and other fields are required.

For a system to be considered a reconfigurable thermal network, it must have the following characteristics:
1. Maintain all components within acceptable temperature ranges autonomously.
2. Adapt to a wide range of component sizes, locations, heat loads, and operating temperatures.
3. Switch between high conductance and low conductance states as dictated by the components.
4. Route heat from hot components to cold components to maximize efficiency.
5. Provide plug-and-play like connectivity between components, panels, and radiators.

The goal is a RTN that can be tailored on-the-fly to the needs of the satellite, the mission, and the space environment. The ultimate goal is a robust and adaptable system that will eliminate the need for point designs and reduce the design cycle from one to three years to one to three days.

PHASE I: Perform sufficient experimentation, testing, and/or analysis to verify the feasibility of materials and designs that satisfy spacecraft thermal management demands and demonstrate reconfigurable thermal control. Develop revolutionary materials and conceptual designs of RTN based on preliminary analysis. Experiments and/or analysis shall be conducted to indicate the practicality of the design in meeting requirements and objectives of typical spacecraft configurations.

PHASE II: Demonstrate the technology identified in Phase I. Tasks shall include, but are not limited to, a detailed demonstration of key technical parameters that can be accomplished and a detailed performance analysis of the technology. A subscale demo is acceptable, but a full-scale demo is encouraged. Also, model validation testing, a detailed evaluation report, and recommendations are required.

PHASE III: Potential military applications are responsive satellites, research satellites, aircraft, and unmanned aerial vehicles. Potential commercial applications for reconfigurable thermal management include aircraft, automobile, microelectronic applications, or any sector where high power densities are required.

REFERENCES:
1. Williams, Andrew and Palo, Scott, “Issues and Implications of the Thermal Control System on Responsive Space Missions.” Proceedings from the 20th Annual AIAA/USU Conference on Small Satellites, Logan, UT, August 2006.

2. Gilmore, David G., Spacecraft Thermal Control Handbook Volume I: Fundamental Technologies, 2nd ed. The Aerospace Press: El Segundo, CA, 2002.

3. Lee, Douglas E., “Space Reform,” Air and Space Power Journal, Summer 2004: pp. 103-112.

4. Lyke, Jim, et al., “Space Plug-and-Play Avionics,” AIAA 3rd Responsive Space Conference, Paper No. RS3-2005-5001, Los Angeles, CA, 25 – 28 April 2005.

KEYWORDS: Thermal Management, Reconfigurable Thermal Control, Thermal Networks

SB082-010 TITLE: Small Engines Designed for High Efficiency, High Power Density and Quiet Operations

TECHNOLOGY AREAS: Air Platform, Ground/Sea Vehicles, Materials/Processes

ACQUISITION PROGRAM: N/A

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 program is the development of small modular engines (10 HP) with the power density and efficiency of large engines (greater than 300 HP). The performance goals are a power density greater than 1 Horsepower per pound (HP/lb.), and greater than 25% thermal efficiency. The engine must also be able to operate on logistically available heavy fuel such as JP8. Furthermore, the engine shall be designed to be mated with an electric generator to gain the advantage of operation at an optimal design point as part of a hybrid electric propulsion system. Small engines typically run at higher rotational speeds than large engines and are a good match with high power density generators. Engine designs which have the potential to be very quiet for systems where a reduced acoustic signature is required are particularly desired.

DESCRIPTION: The design of engines for propulsion has been extensively studied with internal combustion engines (1-5) and gas turbine engines (6) representing mature technology. Small engines (10 HP and below) which are the focus of this topic have not been as extensively developed and optimized, and present design challenges for high performance Defense applications. Hybrid electric propulsion systems (7) are attractive at power levels of interest in this topic, where the engine can be optimized for 'cruise conditions' and battery power can be used for peak power requirements to optimize system performance. Electric power consumption for sensors and communication is also provided by a hybrid electric system. Innovation is required to develop small engines with high performance as described in this topic.

There are a large variety of engine types that could in principle be adapted such that they meet topic goals for power density (> 1 HP/lb.), efficiency (>25%) and quiet operation. Each engine type has its own design specific advantages and challenges. Internal combustion (IC) engines are usually simple 2 stroke engines in this power range with exhaust ports instead of valves. Designs for a small 4 or more stroke engine with enhanced performance will need to address the problems associated with valve actuation at high rpm. IC engine may require 4 or more cylinders for reduced acoustic signatures desired and this would increase thermal losses while also increasing friction in the engine. Turboelectric designs at small size scale also present design challenges including stabilizing the combustion and dealing with thermal losses. Rotary engines are also a design option with seal wear and friction being just one problem to overcome.

Meeting topic goals may require innovation in both materials of construction as well as design. Higher operating temperatures may be required to increase engine efficiency requiring higher temperature capable materials. Increased surface to volume in small engines may require use of insulating materials not needed in larger engine variants. Frictional losses in small engines may require new tribological approaches.

PHASE I: Feasibility study to show that innovative concepts in the design of the small engine meets or exceeds program goals taking into account the thermomechanical and tribological aspects of the design.

PHASE II: Build the engine designed in phase I including the electrical generator and measure the noise levels, power density, efficiency and durability of the engine.

PHASE III: A quiet engine in the 10 HP range would be ideal for emergency electric power backup for homes. It would also be useful for quiet marine propulsion systems such as those used for recreational fishing. Electric delivery vehicles designed for use in urban environments could also make use of a small engine to recharge batteries while making deliveries.

REFERENCES:
1. Internal combustion engine, From Wikipedia, http://en.wikipedia.org/wiki/Internal-combustion_engine

2. Philip Hill, Carl Peterson, "Mechanics and Thermodynamics of Propulsion, 2nd Edition", Prentice Hall, 1991.

3. Richard Stone, "Introduction to Internal Combustion Engines, 3rd Edition", Co-published by SAE and Macmillan, 1999.

4. Gordon Blair, "Design and Simulation of Four-Stroke Engines", Society of Automotive Engineers, Warrendale, PA, 1999.

5. Kevin L Hoag, "Vehicular Engine Design", Springer-Verlag New York, LLC, 2005.

6. J.L. Kerrebrock, Aircraft Engines and Gas Turbines, Second Edition, The MIT Press, London, 1992.

7. Hybrid Vehicle, Wikipedia http://en.wikipedia.org/wiki/Hybrid_vehicle

KEYWORDS: Engines, Hybrid Electric, Turboelectric, Internal Combustion Engine, Rotary Engine

SB082-011 TITLE: High Power Density Electric Motors for Hybrid Electric Air Platforms

TECHNOLOGY AREAS: Air Platform, Materials/Processes

ACQUISITION PROGRAM: N/A

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

OBJECTIVE: Design and prototype high power density electric motors for an all electric vertical takeoff and landing uninhabited air vehicle.

DESCRIPTION: Hybrid electric propulsion offers increased architectural flexibility in both ships and land vehicles, but much less attention has been given to air vehicles. The military utility of helicopters is currently limited by high maintenance costs and vulnerability to small arms fire while landing in hostile territory. The power plant of choice for helicopters is a gas turbine engine due to its high power density. However, the high shaft rpm of a turboprop gas turbine requires a large transmission which may weigh more than the engine due to the much lower rpm rotor which provides lift to the helicopter. If the transmission can be replaced with a motor-generator pair, many of the high maintenance components in the drive train can be eliminated, resulting in reduced operation and support cost comparable to fixed wing aircraft. A hybrid electric drive would also allow the use of a larger number of smaller rotors or electric driven ducted fans, and even the elimination of the tail rotor, which would reduce vulnerability to small arms through redundant systems.

One obstacle to hybrid electric motors is the relative low power density of available electric motors. Commercial off the shelf electric motors have been designed for high efficiency, but power densities are low (~0.1 Horse Power per pound, HP/lb). Electric motors developed for aircraft propulsion have power densities between 1 and 2 HP/lb. Power density of electric motors/generators increase with the operating speed and so direct drive generators can have extremely high power densities (greater than 5 HP/lb).

The challenging problem for this topic is to design and prototype a 7 HP electric motor with a power density greater than 5 HP/lb, efficiency greater than 95% and an operating RPM of less than 10,000 revolutions per minute (RPM). The electric motor produced would be useful for powering a ducted fan (less than 12 inches in diameter) and capable of producing a high thrust to weight for small vertical takeoff and landing UAVs. These goals are intended to push the state of the art in high energy density electric motors. It is anticipated that innovation in both design and materials will be needed to meet these goals. High energy product magnetic materials will be useful in shrinking the size of the motor. Ring motors may be particularly suitable for ducted fans although novel designs using a central shaft may also be appropriate.

PHASE I: Feasibility study to show that the innovative approach in the design of the motor meets or exceeds program goals taking into account the mechanical and electrical aspects of the design.

PHASE II: Refine the design from Phase I and build a prototype ducted fan and electric motor meeting the program goals (7 HP, 8,400 RPM, greater than 5HP/lb, and efficiency greater than 95%).

PHASE III: Electric motors with power densities greater than 5 HP/lb will enable vertical takeoff and landing aircraft with operational and support costs similar to fixed wing aircraft. Commercial applications include short haul air transportation and emergency air vehicles for evacuation of accident victims. The use of the electric motors in lift fans within wings offer the potential for longer range air transport. Higher power density motors also have applications in reducing the weight of consumer products with electric motors such as vacuum cleaners.

REFERENCES:
1. Uninhabited Air Vehicles: Enabling Science for Military Systems, The National Academies Press, 2000. http://www.nap.edu/books/0309069831/html/R2.html

2. Jeffrey J. Berton, Joshua E. Freeh, and Timothy J. Wickenheiser. “An Analytical Performance Assessment of a Fuel Cell-Powered, Small Electric Airplane,” NASA/TM-2003-212393, Glenn Research Center, Cleveland, Ohio, June 2003, Available electronically at http://gltrs.grc.nasa.gov

3. Guerrero I., Londenberg K., Gelhausen P., Myklebust A. “A Powered Lift Aerodynamic Analysis for the Design of Ducted Fan UAVs,” AIAA-2003-6567, 2nd AIAA “Unmanned Unlimited” Conf and Workshop and Exhibit, San Diego, CA, Sept 15-18, 2003.

4. Freeh, Joshua et. al. “Electrical Systems Analysis at NASA Glenn Research Center: Status and Prospects.” NASA/TM-2003-212520. http://www-psao.grc.nasa.gov/publications/TM-2003-212520.pdf

KEYWORDS: Electric Motor, Helicopter, Hybrid Electric, Ducted Fan

SB082-012 TITLE: Universal Sample Preparation Device for Biological Detection

TECHNOLOGY AREAS: Biomedical

ACQUISITION PROGRAM: N/A

OBJECTIVE: Create a nucleic acid sample preparation system which will rapidly generate a sample that can be used in many biological detector systems.

DESCRIPTION: DARPA is interested in developing a biological sample preparation system that will produce samples capable of being used in many different assay systems. One of the major hurdles to deployment of reliable and functional biological sensor instruments is simplification of rapid, reliable and consistent sample collection and preparation [1, 2]. Several factors make “in the field” sample collection difficult. First, there is currently no single sample method that is universally applicable to many sample sources. Additionally, in a deployed situation, a sterile working environment is not available, so contaminants are often present in the sample being processed. Finally, sample preparation protocols are often complex and difficult to perform for untrained users. In military situations, deploying scientifically trained personnel to every location that sampling needs to be performed is not possible. The need for a simple, near universal system for biological sample preparation in both military and civilian arenas is clear.

This SBIR solicits development of an easy-to-use, deployable, reliable sample preparation method for nucleic acids that rapidly generates a sample ready for use in a wide variety of diagnostic equipment. The sample preparation system should be entirely self-contained, and allow rapid sample preparation from a wide range of input materials. Ultimately, this SBIR seeks to develop a product for sample generation that will enable the end user to perform a minimal procedure to prepare the sample in a sample device that will be directly attached to the biological detector for assaying.

PHASE I: Feasibility study of a method of nucleic acid preparation. Feasibility study should demonstrate reliable production of analysis-ready sample from no less than two sample matrices.

PHASE II: Further develop method from Phase I into field-applicable product. This product should generate a sample from many different sources that is suitable for use in several detector platform methods. Additionally, the final prepared sample should be in a chamber that enables direct delivery of the sample to the detector from the sample preparatory apparatus.

PHASE III: Testing technologies developed through this SBIR have wide application in military field testing, military medical diagnostic testing. Additionally, this technology would be well suited for use in civilian homeland defense testing situations. This technology may be evaluated for specific sample materials relevant in clinical settings.

REFERENCES:
1. “Current and Developing Technologies for Monitoring Agents of Bioterrorism and Biowarfare” Lim DV, Simpson JM, Kearns EA, and MF Kramer. Clinical Microbiology Reviews. 2005, 18(4) 583-607.

2. “Nucleic Acid Approaches for Detection and Identification of Biological Warfare and Infectious Disease Agents” Ivntski D, O’Neil DJ, Gattuso A, Schlicht R, Calidonna M, and R Fisher. Biotechniques 2003, 35(4) 862-869.

KEYWORDS: Biomedical

SB082-013 TITLE: Radiation Resistant Fabrics

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study to develop new fabrics or materials that block radiation, and that compare favorably to commercially available radiation-blocking materials in terms of performance and cost-effectiveness.

DESCRIPTION: Radiation is a danger faced by the warfighter, the physician, and the first-responder in many different scenarios. Traditionally, radiation protection for these individuals has been virtually non-existent, or consisted of shields created from lead and other heavy, dense metals. More recently, new material substances have been developed to replace lead in this role [1]. These new material substances are most often integrated into garments as protective sheets or layers of polymer that add protective properties to a garment [2]. In all cases, incorporating protective properties into a garment has a negative effect on the wearability or utility of the garment. When lead is incorporated, the garment becomes heavy, retains heat and moisture, and becomes inflexible. When other materials are incorporated as polymer layers, the garments retain heat and moisture, become thicker than normal garments, and tears or holes in the protective layer may not be visible as the garment is multilayered. Additionally, in the case of both new materials and lead, exposure to the radiation-blocking material itself may prove hazardous to the wearer, should the fabric of the garment tear and the wearer become directly exposed to the material. In most cases, the costs of garments integrating the newly developed radiation-blocking materials are very high, making them impractical for widespread use in military, medical, or first-responder settings.

Many scenarios of terrorist attack in civilian and military theatres predict the usage of radiation dispersal devices (RDDs), or conventional explosives used as a method for disseminating radioactive material, which is typically described as a “dirty bomb”. In any scenario involving a dirty bomb or RDD, first-responders and military personnel would likely be exposed to radiation in both the response/rescue stage of the attack, and also in the decontamination stage of the attack aftermath [3]. The currently available and previously described garments are not suitable for the needs of either group in this situation.

This SBIR seeks development of novel fabrics or materials useful for radiation shielding in military and civilian settings. The developed fabrics or materials should be equivalent to or better than currently available radiation shielding technologies in areas of radiation attenuation, comfort for wearer, flexibility, and durability. Importantly, developed fabrics or materials must also be cost-effective, to enable widespread military and civilian usage in radioprotective garments.

PHASE I: Determine the feasibility for the development of radiation blocking fabric including developing a cost-effective fabric that is equivalent to or better than current commercially available fabrics (Demron, Xenolite) for radiation attenuation in the Cs-137 emission range. Study should address potential cost of development of any proposed fabric.

PHASE II: Develop the materials identified in Phase I into radiation blocking garments suitable for extended wear. Fabrics should be flexible, durable, and not retain heat or moisture to increase usability of garment over those currently available. Garments produced should be as resistant to Cs-137 radiation as commercially available alternatives. The fabric produced should be inexpensive enough to produce a radioprotective garment for less than $500/garment.

PHASE III: The technology developed through this SBIR can be used not only for protection of military personnel; it can also be used by first responders and medical workers in civilian settings.

REFERENCES:

1. “Radiation Transmission Measurements for a Lightweight Fabric” Friedman HW, Singh MS, and RF DeMeo. American Nuclear Society 2003 Annual Meeting. 17 January 2003.

2. “Evaluation of non-lead-based protective radiological material in spinal surgery” Scuderi GJ, Brusovanik GV, Campbell DR, Henry RP, Kwon B, and AR Vaccaro. Spine J. 6 (2006) 577-582.
You can view the abstract and purchase the article at:
http://www.find-health-articles.com/rec_pub_16934731-evaluation-non-lead-based-protective-radiological-material-spinal.htm.

3. “Scenario of a dirty bomb in an urban environment and acute management of radiation poisoning and injuries” FKC Chin. Sing Med J. 2007, 48(10) 950-957.

KEYWORDS: Materials / Processes

SB082-014 TITLE: Single Wall Carbon Nanotube Printed Integrated Circuits

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study of printed integrated circuits (PIC) based on thin film transistors (TFT) constructed of single wall carbon nanotubes (SWCNT). Demonstrate in Phase II the fabrication and function of complementary TFT circuits constructed primarily from SWCNT materials using printing techniques.

DESCRIPTION: Printed integrated circuits today are based upon organic materials (polymers and small molecules) that limit the performance and applicability of the resulting circuits. In particular, these organic materials have low carrier mobilities (~10-2 cm2/V/sec in P3HT) and few choices for n-type materials, yielding TFTs useful only in low-speed, low-density applications like displays and Radio Frequency Identification (RFIDs). These materials also suffer generally from substantial performance degradation when exposed to ambient environments. Fabrication is difficult owing to the integration of numerous heterogeneous materials with different fabrication constraints. Fabrication of complementary devices is extremely difficult (and not practiced commercially), greatly increasing the power requirement and complexity of the PIC in a given application.

Recent advances in SWCNT materials suggest a means to radically improve PICs by using printed TFTs constructed primarily from SWCNT materials. It is well-established that SWCNTs have electronic structure tied to the chirality of the graphene sheet of which they are comprised. Depending on the chirality, SWCNT can be either semiconducting with extremely high carrier mobilities (>1000 cm2/V/sec) or metallic with very low resistivity (< 1 microOhm-cm). These properties are orders of magnitude better than current printed electronic materials and rival those of Si-CMOS devices. Further, it has been shown that the electrical properties on SWCNTs are highly sensitive to chemical functionalization making them attractive transduction elements in a variety of sensing applications. SWCNT are extremely robust in high temperature, high humidity environments and it is reasonable to suppose that the processes for printing SWCNT materials will be compatible with a variety of common printing techniques (commercial dispersions of SWCNT are available). A major difficulty, however, in the fabrication of SWCNT thin film electronics, however, has been the inability to access SWCNT materials with a narrow distribution of chirality and size (and corresponding electronic properties). All SWCNT fabrication processes known today create complex mixtures of materials of different chirality and their separation after fabrication has been difficult. A variety of separation techniques are now in development including a recently published selective etching and centrifugation techniques. Another challenge is the control of majority carrier type and doping within the semiconducting SWCNT. Both n-type and p-type devices are needed to create complementary devices. It has been recently demonstrated that surface functionalization techniques can be used to control the majority carrier type. Further, it is necessary to identify materials and processes to use as gate insulators.

As compared to some other efforts to create transistors using SWCNT that emphasize nanometer scale devices that might compete with Si CMOS, this effort emphasizes technologies that will dramatically improve the state of the art in printed electronics and, thereby, open new application opportunities in areas such as distributed, multifunctional sensors, medical diagnostics, structurally embedded/integrated electronics, rapid IC prototyping, and environmentally hardened electronics.

PHASE I: Prepare a feasibility study of printed integrated circuits (PIC) based on thin film transistors (TFT) constructed of semiconducting SWCNT material for the semiconducting channels, metallic SWCNT for the metallic contacts and interconnects, and polymeric gate insulators. The study should include a thorough review of the published literature and trade analysis of the component technologies and fabrication processes. Determine the viability of techniques used to separate SWCNT on the basis of their electronic and/or physical structure. Determine the feasibility of controlling the carrier type (n-type and p-type) and doping level in high mobility SWCNT semiconducting films for use in the construction of complementary TFT circuits. Determine options for high quality gate insulating materials allowing low-voltage, non-hysteretic operation. Determine the options for SWCNT inks with appropriate properties for use in a printing process (e.g. ink jet, gravure or other printing technique). Evaluate techniques for the low cost printing of SWCNT TFT PICs on rigid and flexible substrates. As part of the final report, the performer will detail a proposed fabrication process and Phase II development plan to implement that process.

PHASE II: The fabrication process from Phase II will be developed and demonstrated. A <5V complementary TFT inverter and a >50 MHz ring oscillator that is robust to exposure to elevated temperature (100 C) and humidity (90% RH) will be demonstrated.

PHASE III: Successful execution of Phase II will lead to broad applicability in defense and commercial markets. Defense applications include distributed, multifunctional, large area sensors (e.g. chemical, optical, RF, IR, acoustic) and integrated/embedded electronics (e.g. small UAVs, helmets, physiological status monitoring, blast dosimetry) that are environmentally hardened and can be implemented on flexible and curved surfaces. Commercial applications include not only penetration of existing PIC markets (displays and RFIDs), but will also open opportunities in medical diagnostics, health monitoring and rapid IC prototyping (imagine printing an IC from a printer connected to your computer).

REFERENCES:
1. Gerwin H. Gelinck et al. "Flexible active-matrix displays and shift registers based on solution-processed organic transistors" Natural Materials 3, 106-110 (2004).

2. Young-Su Lee and Nicola Marzari, "Cycloaddition Functionalizations to Preserve or Control the Conductance of Carbon Nanotubes," Phys. Rev. Lett. 97, 116801 (2006).

3. Guangyu Zhang et al. "Selective Etching of Metallic Carbon Nanotubes by Gas-Phase Reaction" Science 314, 974-977 (2006).

4. Michael S. Arnold et al. "Sorting carbon nanotubes by electronic structure using density differentiation" Nature Nanotechnology 1, 60-65 (2006).

5. Seong Jun Kang et al. "High-performance electronics using dense, perfectly aligned arrays of single-walled carbon nanotubes" Nature Nanotechnology 2, 230-236 (2007).

6. Qing Cao et al, "Bilayer Organic-Inorganic Gate Dielectrics for High-Performance, Low-Voltage, Single-Walled Carbon Nanotube Thin-Film Transistors, Complementary Logic Gates, and p-n Diodes on Plastic Substrates" Adv.

Funct. Mater. 16, 2355-2362 (2006).

7. See for example, Zhihong Chen et al, "An Integrated Logic Circuit Assembled on a Single Carbon Nanotube," Science 311 1735 (2006).

KEYWORDS: Rocket, Pumps, Interceptors, Launch, Vehicle, and Propulsion

SB082-015 TITLE: Portable Medical Recorder

TECHNOLOGY AREAS: Information Systems, Biomedical, Electronics, Human Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Although modern transportation allows for the rapid medical evacuation of warfighters, there is currently minimal capability to transfer accurate information regarding the conditions in which they were injured as well as accompanying medical records and patient specific needs. By constructing a digital voice recorder that meets the approximate form factor of the modern dog tag (1” x 2” x .5”) and is capable of dealing with the challenges of the operating environment both in terms of noise filtration and ability to withstand physical and environmental damage, we seek to improve combat casualty care and prevent downstream complications that may arise from an imprecise understanding of events at point of injury.

DESCRIPTION: Digital voice recorders have the capability to solve a serious problem in current medical care of the warfighter. Currently, continuity of records is limited between initial point of injury and final point of care in CONUS. By providing a small form factor solution, analogous to the current dog tag, capable of withstanding physical and environmental insult as well as actively reducing ambient noise, pertinent medical information could be carried forward in a secure and continuous fashion.

The voice recorder must be able to withstand:
- Temperature: 0 C to 50 C.
- Pressure: 80 psi.
- Duration: 4 hours of active use, both playback and recording.
- Must fit into a form of 1” x 2” x .5”.

Additionally, the device must be capable of minimizing ambient noise while retaining the clarity of vocal recordings made by attending medical personnel. The military environment has a dynamic range of background noise, ranging from multiple 140 dB events (rifle shot) to persistent background noise above 100 dB (jet engine during air evacuation). These sources must be actively minimized, so that the medical recording can be played back without loss of fidelity of voice at following levels of care.

PHASE I: Prepare a feasibility study for a noise cancelling portable voice recorder. During the first phase, the performer will propose a conceptual device, signal processing algorithm, and a preliminary design. A report will be generated. As part of the final report, plans for Phase II will be proposed.

PHASE II: Develop a prototype based on the preliminary design from Phase I. All appropriate engineering testing will be performed. A critical design review will be performed to finalize the design and prototype units will be manufactured and tested.

PHASE III: Miniature portable voice recorders capable of ambient noise reduction could be used in a variety of settings. In addition to allowing patients to carry portable medical records in a form factor, this will allow carrying any type of record similarly. It will have broad application in the civilian commercial market from anything from personal organization to business documentation.

REFERENCES:
1. Multichannel post-filtering in nonstationary noise environments Cohen, I.; Signal Processing, IEEE Transactions on [see also Acoustics, Speech, and Signal Processing, IEEE Transactions on] Volume 52, Issue 5, May 2004 Pages

1149 – 1160.

2. Background noise reduction via dual-channel scheme for speech recognition in vehicular environment Sungjoo Ahn; Hanseok Ko; Consumer Electronics, IEEE Transactions on Volume 51, Issue 1, Feb. 2005 Pages 22 – 27.

3. Beamforming microphone arrays for speech acquisition in noisy environments Sven Fischer and Klaus Uwe Simmer; Speech Communication, Volume 20, Issues 3-4, December 1996, Pages 215-227.

4. Optimized second-order gradient microphone for hands-free speech recordings in cars Roland Aubauer and Dieter Leckschat; Speech Communication, Volume 34, Issues 1-2, April 2001, Pages 13-23.

5. A New Approach for Rustle Noise Canceling in Pen-type Voice Recorder Ki-Man Kim, Young-Keun Choi, and Kyu-Sik Park; IEEE Transactions on Consumer Electronics, Vol. 49, No. 4, Pages 1118-1124.

6. DSP-Implemented Broadband Superdirective Microphone Array with Audible Noise Suppression Sanchez-Bote, J.-L., Gonzalez-Rodriguez, J., Ortega-Garcia, J. AES: Journal of the Audio Engineering Society Volume 53, Issue 5, 2005, Pages 403-418.

7. Design of a MEMS acoustical beamforming sensor microarray Chowdhury, S.; Ahmadi, M.; Miller, W.C.; Sensors Journal, IEEE Volume 2, Issue 6, Dec. 2002 Pages 617 – 627.

8. A spatio-temporal speech enhancement scheme for robust speech recognition in noisy environments Erik Visser, Manabu Otsuka, and Te-Won Lee; Speech Communication Volume 41, Issues 2-3, October 2003, Pages 393-407.

9. Robust speech processing using multi-sensor multi-source information fusion—an overview of the state of the art Parham Aarabi and Belur V. Dasarathy; Information Fusion Volume 5, Issue 2, June 2004, Pages 77-80.

KEYWORDS: Digital Recorders, Piezoelectric Sensors, Digital Storage, Medical Records

SB082-016 TITLE: Multi Input Wireless Look-Through Heads Up Display (HUD) for Use in Multiple Extreme Environments

TECHNOLOGY AREAS: Information Systems, Electronics, Human Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop a small look through heads up display with an industry standard wireless interface that is capable of toggling between four separate input data streams. The device must be able to operate, without modification, in high altitude conditions and in subsurface dive operations in depths up to 190 feet and in extreme terrestrial conditions.

DESCRIPTION: Special Operations Forces operate in the extremes of air, land and sea and use a multitude of stand alone navigation and sensor platforms during missions that occur in single or multiple environmental domains.

The Defense Advanced Research Projects Agency seeks to create a common Heads Up Display (HUD), with wireless input. The display must be capable of transiting from one environmental domain to another without modification and be capable of withstanding the temperature and pressure extremes outlined below:
- Air: 35,000ft to sea level (temp -65.6 ºF to +60 ºF, 3.5 psi and 14.7 psi).
- Sea: Sea level to 190ft (temp 29 ºF to 104 ºF, 14.7 psi to 97 psi).
- Land: 140 ºF.

In addition the device must be capable of withstanding exposure to common contaminants such as sand, dust, salt water, and oil.

Although there are short distance wireless interface protocols for connecting a wide array of devices the transmission medium is almost exclusively air. In air acoustic and radio waves will attenuate because of spherical spread, the attenuation is inversely proportional to the radius of the sphere representing the distance of the wavefront from the source or 1/R2. In addition to the losses due to spread, they also experience absorptive losses. The losses experienced when transmitting radio signals through water are significantly increased as compared to the losses in air. The losses are frequency dependent and they increase in direct proportion to the increase in frequency. Underwater communication systems typically employ the VLF or LF bands to minimize the absorptive losses over distance but the use of low frequency severely limits the data transmission bandwidth. [2] The high frequency regime of industry standard wireless protocols, 2.4GHz to 10.6 GHz, is not ideally suited for transmission in water but due to the short transmission distance, less than 2 meters, should not drastically impact the required transmitter power.

The preliminary specifications of the wireless display unit are as follows:
- 800 x 600 dpi or capable of NTSC video.
- Readable in indirect sunlight.
- Dimming 5-500 NIT.
- Industry standard wireless protocol enabled.
- Redundant hardwire connection.
- Hardened against environmental conditions and contaminants.
- Minimum of 4 input channels.
- Single button toggling between data input streams.
- Less than 6 cubic inches in volume.
- 6 hour battery life.

PHASE I: Conduct a study to access the feasibility of producing a wireless look-through head mounted display that can withstand the environmental extremes experienced on land, at high altitude and underwater. The study must produce a conceptual design, with supporting data and/or analysis, that addresses packaging issues, the feasibility of using an industry standard wireless protocol in all environments, transmitter power requirements in all environments, data transmission rate estimates, and estimated power consumption for the proposed design.

PHASE II: Construct a prototype device to be tested in operationally relevant environments with a variety of DARPA-defined input displays. The device must be tested against all of the outlined environmental conditions, show the ability to toggle between 4 separate data-stream displays and demonstrate 6 hours of uninterrupted operation in average climate conditions. Environmental impact on battery life should be characterized, and a study should outline the incorporation of data security measures into the hardware.

PHASE III: A wireless enabled heads up display that is hardened to operate while withstanding the environmental limits of high altitude, diving depths, and terrestrial extremes, can be used in a multitude of commercial applications. For example, the construction industry relies on a multitude of handheld devices that supply critical information for navigation, status of critical equipment, and communication, in particular for undersea or underground construction projects. A stand-alone wireless heads up display could serve as an integrated interface for these devices.

REFERENCES:
1. United States. National Oceanic and Atmospheric Administration. “U.S. Standard Atmosphere 1976”, U.S. Government Printing Office, Washington, D.C., 1976.

2. Heidemann, John; Li, Yuan et al,. “Underwater Sensor Networking: Research Challenges and Potential Applications” USC/ISI Technical Report ISI-TR-2005-603, 2005.

3. United States Navy. U.S. Navy Diving Manual Vol 4, 2002.

4. Agere, Hewlett Packard et al. Wireless Universal Serial Bus Specification, Rev 1.0, May 2005.

KEYWORDS: Heads Up Display, Wireless, Diving, Parachuting

SB082-017 TITLE: High-Power, Narrow Linewidth Laser Diodes for Alkali Atoms

TECHNOLOGY AREAS: Air Platform, Ground/Sea Vehicles, Sensors, Space Platforms

ACQUISITION PROGRAM: N/A

OBJECTIVE: This program will develop high power, narrow linewidth, and single-mode laser diodes suitable for next-generation atom sensors.

DESCRIPTION: Alkali metals (Li, Na, K, Rb, and Cs) are currently the workhorse of laser cooling and trapping. Cesium and Rubidium, in particular, are often used because of the accessibility of cheap and reliable laser diodes that operate at the requisite frequencies. Now, recent work with ultracold fermions suggests that Lithium and Potassium may prove useful for atom interferometry1. By providing the atomic physics community with more powerful and stable laser sources at the alkali wavelengths, this program seeks to accelerate deployment of atom-based sensors.

The recent development of laser cooling and trapping has brought forth a new paradigm in precision metrology. Cold atom-based systems have already demonstrated unprecedented capabilities for timekeeping (2), inertial sensing (3), and magnetometry (4). These first-generation sensors are laboratory-scale and require the care of highly-trained specialists to operate. In order to realize their full potential, atom-based sensors must be brought outside of the benign, controlled laboratory environment. To this end, several DARPA programs seek to miniaturize and ruggedize atom-based sensors for deployment in the field.

A key component of cold atom-based sensors is the lasers used for cooling, trapping, and probing the atomic species. Any attempt to build a robust atom sensor necessarily requires a major engineering effort to construct a compact, stable laser system. The use of distributed feedback (DFB) laser diodes provides an excellent approach for achieving the requisite operating conditions. With the grating built into the face of the diode, narrow-band operation requires no external cavity, decreasing the size of the laser system while also greatly increasing its stability. High output power would reduce system complexity by eliminating additional components such as tapered amplifiers or slaved-diodes.

PHASE I: Prepare a feasibility study to assess the potential for producing narrow linewidth (<1 MHz), single-mode laser diodes at the following target powers and wavelengths: >150 mW @ 780 nm (rubidium), > 200 mW @ 852 nm (cesium), >100 mW @ 670 nm (lithium), and >150 mW @ 767 nm (potassium). Design the laser diodes and conduct preliminary design reviews. A report will be generated. As part of the final report, plans for Phase II will be proposed based on wavelength(s) that show the most promise for atom-based sensing.

PHASE II: Fabricate prototype laser diodes and package 10 units per selected wavelength for characterization and delivery to DARPA. Provide, at minimum, data showing linewidth and power measurements (e.g., L-I curve), tuning characteristics including temperature tuning and modulation transfer function for RF sideband modulation.

PHASE III: Cold atom-based systems have already demonstrated unprecedented capabilities for timekeeping, inertial sensing, and magnetometry. Potential commercial use would include LORAN (a coastal navigation system supported by DOC timekeeping stations), cell-phone towers, etc.

REFERENCES:
1. E. Andersson et al., “Multimode Interferometer for Guided Matter Waves,” Physical Review Letters, Vol. 88, 100401 (2002).

2. “NIST-F1 Cesium Fountain Atomic Clock.” National Institute of Standards and Technology. http://tf.nist.gov/timefreq/cesium/fountain.htm.

3. T. L. Gustavson, P. Bouyer, and M. A. Kasevich, “Precision Rotation Measurements with an Atom Interferometer Gyroscope,” Physical Review Letters 78(11), 1997: 2046-2049.

4. M. Vengalattore et al. “High-Resolution Magnetometry with a Spinor Bose-Einstein Condensate,” Physical Review Letters 98, 200801 (2007).

5. Power is referenced to 780 nm, other wavelength values should be similarly aggressive.

KEYWORDS: DFB, Laser Diode, Atomic Physics, Laser Cooling and Trapping

SB082-018 TITLE: Novel Software Tools for Analyzing Massive Datasets

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study to develop a robust software tool for analyzing massive data sets using topological methods.

DESCRIPTION: Massive Data sets are ubiquitous across defense applications. Current software tools are either overwhelmed by the sheer amount of data, or if they can handle the data volume, require tool-specific expertise. There is a need to develop a software tool that not only can handle complex data sets, but is also robust, user-friendly and multi-functional.

Traditional mathematical approaches are easily overwhelmed by the sheer scale of realistic problems. However, recent developments in mathematical concepts and techniques that determine the fundamental geometric structures within massive data sets allow exploitation of topological structures hidden in the data, revealing properties of massive data sets otherwise hidden or requiring enormous amounts of time to extract. Having a tool that makes extraction of these geometric data characteristics simple and straight forward would be advantageous to many military applications, and applications in the healthcare industry, medical studies, logistics, and manufacturing.

The software tools developed in this SBIR should have broad impact across several avenues of defense applications. The tool should exploit cross-cutting, easy to use topological algorithms that exhibit and extract hidden properties of massive data sets robustly across a wide variety of applications.

PHASE I: Prepare a feasibility study for creating a topological software tool to analyze massive data sets. During the first phase, the performer will propose a plan to transform topological theories into a user-friendly software platform. Design of the concept will be performed and a preliminary design review and report will be generated. As part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized. All appropriate software testing and validation of design issues will be performed. A critical design review will be performed to finalize the design and a prototype software tool will be developed and tested.

PHASE III: There are both military and commercial applications of this technology in data analysis across a broad range of topics: health care, medicine, logistics, and manufacturing.

REFERENCES:
1. G. Carlsson and A. Zomorodian, “The Theory of Multidimensional Persistence,” 23rd ACM Symposium on Computational Geometry, Gyeongju, South Korea, June 6–7, 2007.

2. H. Edelsbrunner, D. Letscher and A. Zomorodian, “Topological persistence and simplification,” Discrete Computational Geometry, 28, pp. 511-533, 2002.

3. P. Niyogi, S. Smale, and S. Weinberger, “Finding the Homology of Submanifolds with High Confidence from Random Samples,” Combinatorial and Discrete Geometry (to appear).

4. G. Singh, F. Memoli and G. Carlsson, “Topological Methods for the Analysis of High Dimensional Data Sets and 3D Object Recognition,” Point Based Graphics 2007, Prague, September 2007.

5. A. Zomorodian and G. Carlsson, "Computing Persistent Homology," Discrete and Computational Geometry, 33 (2), pp. 247–274, 2005.

KEYWORDS: Data Analysis, Topology, Geometry

SB082-019 TITLE: Ground Moving Target Indicator (GMTI) Radar Discrimination of Combatants versus Animals in Severe Clutter

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

ACQUISITION PROGRAM: N/A

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 advanced techniques in radar mode management and processing for discriminating combatant dismounts and wildlife, under foliage and similar hide/camouflage conditions, based on radar high resolution waveforms and motion behavior analysis.

DESCRIPTION: GMTI radar provides a robust capability for detecting moving targets, both in the open and hidden in foliage. The tactical targets include both ground vehicles and dismounted troops in remote areas. Several GMTI radars are being studied or are under development by DARPA and the Army for Unmanned Aerial Systems that have the potential for efficient detection of dismounted combatants. Once a target cue is obtained by these systems, a dedicated radar waveform can illuminate the target to discriminate whether it is a vehicle, a dismount or possibly an animal. Discriminating single humans and groups of humans from animals is a significant challenge because of the similar speed of movement and radar cross-section. This is particularly difficult in areas masked by foliage and other shallow hide conditions. The radar high range resolution and Doppler spectral returns can be analyzed to potentially determine the characteristics of the body motion and (possibly) the number of legs and characterize the leg motion to discriminate humans from animals.

PHASE I: Generate synthetic radar returns and/or analyze existing radar returns using detailed scattering models of humans and animals to develop and test prototype algorithms. Where required, incorporate the effects of the radar operating frequency, volumetric clutter and foliage attenuation and internal clutter motion, to determine the feasibility of discriminating humans from animals in radar data.

PHASE II: Collect calibrated, ground truthed radar measurements of humans and animals in foliage and shallow hide conditions with a suitable GMTI radar testbed. Develop algorithms to reliably discriminate single and groups of dismounts and animals of similar size (e.g. deer, large dogs, horses, cattle). Quantitatively evaluate the algorithm performance and define radar waveforms and operating modes to maximize the probability of discrimination.

PHASE III: The technology developed under this SBIR will minimize false alarms in emerging DOD and DHS semi-autonomous radar or radar-networks used for reconnaissance and perimeter surveillance. Applications include force protection and perimeter surveillance for facilities located in forested areas.

REFERENCES:
1. Forester web description.
http://dtsn.darpa.mil/ixo/ixopro_new.asp?id=37

2. Vehicle and Dismount Exploitation Radar (VADER) web description.
http://dtsn.darpa.mil/ixo/ixopro_new.asp?id=166

KEYWORDS: GMTI radar, Foliage Penetration (FOPEN) Radar, Dismount Detection, Target Discrimination

TPOC: Dr. Mark E. Davis
Phone: (571) 218-4688
Fax: (703) 248-1862
Email: mark.e.davis@darpa.mil

SB082-020 TITLE: Robust Wideband Waveforms for Synthetic Aperture Radar (SAR) and Ground Moving Target Indication (GMTI) Applications

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

ACQUISITION PROGRAM: N/A

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 and estimate the performance of innovative wideband waveforms for SAR GMTI systems that are robust to realistic operating considerations, to include spectral notching to prevent interference to other co-band systems, narrow-band radio frequency interference, and transmitter and receiver effects such as saturation and filtering.

DESCRIPTION: The contractor shall develop one or more innovative wideband waveform concepts for very high resolution SAR and GMTI operation. The SAR/GMTI systems are to include those having resolutions of finer than 1 meter that are currently being developed at UHF, and systems having resolutions of finer than 0.15 meter that are currently being developed at microware frequencies. The waveforms require long dwells over a wide bandwidth affecting the surveillance system’s area coverage rate. To achieve such fine resolutions, these radars often overlap the frequencies being used by other co-band radars, and can even broadcast beyond the portions of the spectrum allocated for radars. As a result, it is often required to notch portions of the radar signal spectrum to avoid interfering with other systems or to avoid being jammed by high-power co-band signals.

A consequence of the notching is that the peak range sidelobes and multiplicative noise ratio (MNR) can become very high, and can greatly diminish the quality of the SAR image. In addition, for the GMTI operation, the adaptive processing to eliminate clutter is affected by the inhomogeneous clutter characteristics. This topic will focus on the development of a class of waveforms that can be used in a state-of-the-art SAR/GMTI system to minimize the impact of the spectral notching.

PHASE I: The contractor shall develop one or more waveform concepts that can mitigate the effects of spectral notching in a wideband SAR/GMTI system. The contractor shall perform a mathematical analysis and computer simulation to show the performance of the waveforms under near-ideal conditions and with simulated, first-order radar transmitter and receiver characteristics.

PHASE II: The contractor shall perform in-depth analyses of the waveforms developed in Phase I, plus any additional waveforms that are identified. The analyses shall include detailed SAR/GMTI simulations, to include the transmitter, receiver, motion compensation, pulse compression, and image formation/adaptive processing. The Phase II effort will quantify the null depths achieved on transmit and receive, and the anticipated peak and integrated processing sidelobes for various spectral notching scenarios, and the impact on minimum discernable velocity on the GMTI. Additionally, the contractor shall develop software for the rapid and efficient generation of the wideband SAR/GMTI waveforms with user-specified spectral notches.

PHASE III: Candidate applications include automation for monitoring both military and civilian borders and automation of security surveillance for events (civilian sector/homeland security).

REFERENCES:
1. Sanders, F. H. et al, Effects of RF Interference on Radar Receivers, NTIA Report TR-06-444, U.S. Department of

Commerce, September 2006.

2. Lindenfeld, M.J., Sparse frequency transmit-and-receive waveform design, IEEE Transactions on Aerospace and Electronic Systems, Volume 40, Issue 3, July 2004.

KEYWORDS: GMTI, SAR, Radar Wideband Waveform, Spectrum Notching

SB082-021 TITLE: Functional Interpretation of Activities and Objects

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop techniques to determine the type, functionality, purpose or intent of static and moving objects from combat aerial video through analysis of dynamic information. Objects of interest include buildings, structures, functional areas and vehicles.

DESCRIPTION: Existing methods for object classification rely primarily on static information available in single-frame images. However, analysts are highly interested in object functionality or purpose as this can provide a further level of classification. Video, and particularly persistent surveillance video, enables the determination of object type or function that would be difficult or impossible in static images. Many challenges exist in automatic functional classification, such as handling errors in moving object detection and tracking, large intra-class variability in the activity involving static structures, and large amounts of clutter traffic in urban areas. DARPA is seeking to develop automatic methods that take advantage of persistent video to identify the type, functionality, purpose and/or intent of both moving and static objects. The specific type of static objects such as buildings can be determined by characterizing the activity around them, such as dismounts entering and exiting and nearby vehicular traffic. Examples include terrorist safe houses, warehouses and weapon caches. The type and/or purpose of moving objects can be assessed by classifying their behavior, such as material transport vehicles, weapon transport vehicles and couriers. Of particular interest are object classes where dynamic information provides a clear advantage in classification over static imagery analysis, e.g. traditional automatic target recognition. Functional Interpretation of Activities and Objects will add a new dimension of information that is not attainable from traditional single-frame imagery. The purpose of buildings may be derived on city-wide scales, and abnormal buildings may be detected such as terrorist safe houses embedded in residential neighborhoods. Moving vehicles may be classified based on functionality when no visual features distinguish them at a given resolution. Furthermore, the algorithms must operate on low resolution video (greater than 10 cm per pixel) from which identification of individuals is not possible.

PHASE I: Develop initial methods for activity-based functional interpretation of activities and objects. Perform initial feasibility studies to estimate the accuracy and robustness of the approach.

PHASE II: Develop, refine and implement the recognition system. Compare with image-based classification methods to demonstrate improved utility on large, realistic data sets. Develop an operational prototype, or integrate the developed tools into an existing system already installed at an appropriate government facility.

PHASE III: Candidate applications of this technology span both military and commercial requirements. In general, the availability of image and video data is growing substantially. Commercially, the proliferation of video cameras for a variety of purposes, such as traffic monitoring, yields fertile territory for a technology which can support detection and analysis of activities of interest. This capability also has applicability to other applications, such as web-based video searches and video-library searches.

REFERENCES:
1. P Peursum, G West, S Venkatesh. “Combining Image Regions and Human Activity for Indirect Object Recognition in Indoor Wide-Angle video.” IEEE Intl. Conference on Computer Vision, 2005.

2. L Stark and K Bowyer. “Achieving Generalized Object Recognition through Reasoning about Association of

Function to structure.” IEEE Transactions on Pattern Analysis and Machine Intelligence, 1991.

KEYWORDS: Activity Recognition, Video Analysis

SB082-022 TITLE: Summarization, Visualization and Browsing of Massive Video Archives

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop new methods for interactive examination and investigation of massive video archives that enable video analysts to quickly examine and filter large amounts of combat aerial video collected for tactical military operations over extended geographic regions for the most salient content.

DESCRIPTION: The proliferation of video sensors, both wide-area and narrow field-of-view, has generated a huge video collection capacity. Currently video archives are examined by humans watching videos, often at super-real-time speeds (fast forward). Even if video query capabilities improve significantly, hours of video may be returned by a single query. Watching all of this video is tedious and highly time-consuming.

DARPA is soliciting techniques to enable video analysts to rapidly browse through huge video archives by providing a geo-spatial, temporal summarization of video data. Significant tracks and salient derived information would be visually summarized based on automatic analysis and prioritization, but without thresholding or filtering to avoid discarding potentially useful information. Video analysts will be able to scan through the derived data to find subtle patterns and anomalies of interest, trends over short or long time periods, and variances between patterns at different times of day, all with point-and-click access to source video clips.

The primary challenges to be addressed are methods for automatically determining which tracks and information to highlight or accentuate how to visualize huge amounts of spatially and temporally dense data without overwhelming the analyst, and techniques for rendering large spatio-temporal data sets in real-time as the analyst pans and zooms. The developed system must go beyond a static or temporal overlay of object trajectories, which does not scale up to long-duration, wide-area video coverage. Furthermore, the algorithms must operate on low resolution video (greater than 10 cm per pixel) from which identification of individuals is not possible.

PHASE I: Develop methods for summarizing video by content saliency, and techniques for visualizing and browsing video summaries such that a video analyst can rapidly exploit the data. Perform initial studies to estimate the feasibility of the approach.

PHASE II: Develop, refine and implement the system. Compare video analyst performance using the summarization and browsing capability against standard exploitation tools on large, realistic data sets. Develop an operational prototype and demonstrate its capabilities.

PHASE III DUAL USE APPLICATIONS: Commercialize the tools by transitioning into an operational program, or integrate the developed tools into an existing production system installed and tested at an appropriate government facility. Work with analysts to demonstrate overall productivity and effectiveness improvements in intelligence yield.

REFERENCES:
1. A Rav-Acha, Y Pritch, S Peleg. “Making a Long Video Short: Dynamic Video Synopsis <http://doi.ieeecomputersociety.org/10.1109/CVPR.2006.179>.” IEEE Conference on Computer Vision and Pattern Recognition, 2006.

2. J. Oh, Q. Wen, J. lee, and S. Hwang. “Video abstraction.” In S. Deb, editor, Video Data Mangement and Information Retrieval, pages 321–346. Idea Group Inc. and IRM Press, 2004.

3. Daniel DeMenthon and David Doermann, "Video Retrieval using Spatio-Temporal Descriptors", ACM

Multimedia 2003, Berkeley, CA, USA, November 2-8, 2003.

KEYWORDS: Visualization, Video Archives, Video Browsing, Video Analysis, Video Content Retrieval

SB082-023 TITLE: Query Refinement for Content-Based Video Retrieval

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop new methods for content-based video retrieval that enable a video analyst to specify, then iteratively refine complex queries involving multiple scene elements, dynamics and context. These methods should scale up to very large databases of video.

DESCRIPTION: Sensors are now capable of collecting massive quantities of wide-area and ground-level video of complex scenes, where dozens, hundreds or even thousands of objects are moving and interacting. Maturing technologies such as moving object detection, tracking and low-level event recognition can reduce the analysts' workload, but they do not provide the high-level analysis and filtering that video analysts require for solving intelligence problems.

A content-based query paradigm would provide an effective means for analysts to find salient activities embedded in large volumes of clutter, but many challenges remain. If a single video exemplar is posed as the query, the resulting query model will be highly specialized compared to the true variability of activities, scene conditions and imaging conditions, and the video exemplar is likely to contain many clutter objects not involved in the activity of interest. Furthermore, the learning of multi-state, multi-actor activity models on training data with errors in detection, tracking, recognition, and so on is an open problem. DARPA is seeking methods for content-based video retrieval that address these issues, and provide highly efficient indexing to scale up to massive video archives. The system should provide an interactive, iterative mechanism for query refinement so that the video analyst can rapidly scan the retrieved clips, select those most relevant for his problem, and launch the query again. The system should refine the query based on the selected clips, and continuously improve the relevance of the top matches. Although this paradigm has been well-developed for image retrieval, this solicitation is specifically interested in techniques that exploit video information in the form of object dynamics, evolving interactions and other temporal information from the combat aerial video collected for tactical military operations. Furthermore, the algorithms must operate on low resolution video (greater than 10 cm per pixel) from which identification of individuals is not possible.

PHASE I: Develop content-based video retrieval formulation, including query representation, refinement approach and efficient indexing. Perform initial feasibility studies to estimate the scalability and accuracy of the approach.

PHASE II: Develop, refine and implement the retrieval system. Compare with image-based retrieval methods to demonstrate improved utility on large, realistic data sets. Develop an operational prototype, or integrate the developed tools into an existing system already installed at an appropriate government facility.

PHASE III: Candidate applications of this technology span both military and commercial requirements. In general, the availability of image and video data is growing substantially. Commercially, the proliferation of video cameras for a variety of purposes, such as traffic monitoring, yields fertile territory for a technology which can support detection and analysis of activities of interest such as traffic accidents. This capability also has applicability to other applications, such as web-based video searches and video-library searches.

REFERENCES:
1. S. Hongeng, R. Nevatia and F. Bremond. "Video-based event recognition: activity representation and probabilistic recognition methods".
http://linkinghub.elsevier.com/retrieve/pii/S1077314204000712
"In Computer Vision and Image Understanding", 96:22, pp. 129-162, Nov. 2004.

2. Michael T. Chan, Anthony Hoogs, Zhaohui Sun, John Schmiederer, Rahul Bhotika and Gianfranco Doretto.

"Event Recognition with Fragmented Object Tracks." In Proceedings of the 18th International Conference on Pattern Recognition, 2006. IEEE, pp. 412-416.

3. Y. Shi, A. Bobick, and I. Essa. "Learning temporal sequence model from partially labeled data". In IEEE Conference on Computer Vision and Pattern Recognition, pages 1631 – 1638, 2006.

4. J. R. Smith, S. Basu, C.-Y. Lin, M. Naphade, B. Tseng, "Interactive Content-based Retrieval of Video", Proc. IEEE Intl. Conf. on Image Processing (ICIP), Rochester, NY, Sept., 2002: Vol. 1 pp. I-976 – I-979.

KEYWORDS: Video Retrieval, Video Content Retrieval, Interactive Query, Query Representation, Video Indexing

SB082-024 TITLE: Novel Accelerator Architectures for Critical DoD Application

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: N/A

OBJECTIVE: Many DoD applications are performance limited by specific components of the application code (processing kernels) that execute inefficiently on conventional microprocessors. This effort will investigate and develop critical processing kernels as accelerators to general-purpose processors, utilizing existing specialized COTS processors.

DESCRIPTION: The performance of many key DoD applications is limited by the execution of specific critical functions or sections of code executed on conventional processors that are ill-suited to perform that function. The commercial world has gotten around this problem by developing several interesting and highly capable, but specialized, commodity microprocessors that accelerate graphics, gaming and network devices. These include processors such as the STORM-1 from Stream Processors, Inc., the Tile64 from Tilera, the NVIDA and ATI GPUs, and the PhysX from Ageia. These architectures provide unique processing resources that can deliver high performance for specific functions. It is anticipated that by designing and developing DoD-relevant functions to take advantage of these unique processing architectures, application performance bottlenecks can be eliminated, resulting in significant overall system performance improvements.

As an example of one effort, DARPA funded a project that explored using GPUs to significantly improve the performance of key kernels in the Army Computer Generated Forces (CGF) simulation application code, OneSAF. The effort reworked small, but critical sections of the simulation code that were performance bottlenecks on an Intel based computer. Line of sight (LOS), region-based visibility, and route-planning codes were reworked to execute on a GPU processor with an architecture that is particularly suited to these demanding code sections. The result in reworking these limited code sections for the GPU processor was a 10-20x overall simulation speed improvement.

DoD applications where performance is limited by specific functional and code elements include: Simulation – at all levels, from chip to battlefield; Weather and environmental modeling; Automatic target detection and identification; Image processing and rendering; Aeroelasticity codes; Turbulent flow models; Shock physics models, Quantum chemistry codes; Ocean circulation models; Molecular dynamics codes; CFD models using overset grids; and Chip and system emulation. Key code functions that impact application performance such as line-of-sight, collision prediction, target isolation and identification, weather and environmental calculations, and other critical functionalities that are key elements of numerous application codes are also of interest. Additional application codes will be considered, particularly those of most relevance to the DoD.

This effort will address performance improvements that can be achieved using specialized COTS processors as accelerators to general-purpose processor, and will determine the impact on specific DoD applications. It is anticipated that the results will create dramatic performance improvements in the specific processing areas investigated and will result in significantly improved capabilities to the warfighter.

PHASE I: Pursue identified performance challenged DoD processing areas, specific functions, algorithms, or processing areas, and develop an implementation utilizing specialized COTS processors to dramatically improve associated processing performance. Establish performance improvements. Develop new algorithms and implementations for the identified functions. For Phase I the improved capability will be established for the specific processing area identified, the implementation approach detailed, and contact with the DoD elements responsible for the system that will be involved. Specific processing areas anticipated include Simulation – at all levels chip to battlefield, Weather and environmental modeling, Automatic target detection and identification, Image processing and rendering, Aeroelasticity codes, Turbulent flow models, Shock physics models, Quantum chemistry codes, Ocean circulation models, Molecular dynamics codes, CFD models using overset grids, and Chip and system emulation. Key code functions that impact application performance, such as line-of-sight, collision prediction, target isolation and identification, specific weather and environmental calculations, and other critical functionalities are also of interest. Additional application codes will be considered, particularly those of most relevance to the DoD.

PHASE II: The design from Phase I will be finalized, implemented, and tuned for the selected applications. Overall system performance improvement and impact to the selected application will be demonstrated. This phase will be coordinated with the DoD elements responsible for the system being affected.

PHASE III DUAL USE APPLICATIONS: Implementation of the processing approach will be fully developed, performance improvements for the selected applications clearly demonstrated, and the implementations transitioned to the relevant military program office. The capabilities and novel processing application techniques developed and lessons learned, regarding the utilization of the advanced architectures, will be applicable to both DoD and commercial high performance processing applications.

REFERENCES:
1. Manocha, Dinesh, Bauer, Maria, Macedonia, Michael, et.al., Accelerating Route Planning and Collision Detection for Computer Generated Forces using GPUS, ASC2006. (http://gamma.cs.unc.edu/LOS/ASC2006.pdf)

2. Manocha, Dinesh, Bauer, Maria, Verdesca, Marlo, et.al., Using Graphics Processor Units to Accelerate OneSAF: A Case Study in Technology Transition, Interservice/Industrial Training, Simulation, and Educations Conference (I/ITSEC) , 2005. (http://www.iitsec.org/documents/R_2121_000.pdf)

3. Manocha, Dinesh, Lin, Ming, Accelerating Line of Sight Computation Using GPUs, Department of Computer Science University of North Carolina at Chapel Hill, August 2005. (http://www.cs.unc.edu/Research/ProjectSummaries/LOS05.pdf)

KEYWORDS: Processing, Architectures, Innovative, Novel Architectures, Processing Performance, Processing Implementations, Applications, Optimization, Processing Functions, Processing Kernels

SB082-025 TITLE: <u>Tactical Telehaptic Communication (HAPTAC)</u>

TECHNOLOGY AREAS: Information Systems, Human Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Research and develop technologies enabling mid-range tactical communication between soldiers through the tactile sensor modality.

DESCRIPTION: Communication between soldiers at the squad level is currently limited to auditory (voice) and visual (hand signals) methods. However, combat situations—particularly in urban settings—severely interfere with these communication channels: explosions generate noise louder than the human voice, rooms in buildings interfere with line-of-sight, and so forth.

DARPA seeks innovative approaches to the exploitation of the tactile sensory modality for communication of tactical information between soldiers at the squad level. This technology would be capable of receiving signals within a range of approximately 300 feet via devices (e.g., electrotactile or vibrotactile arrays) placed near or on the soldier’s skin. Technology used to send signals to the telehaptic receiver may also be a haptic device (e.g., haptic glove); in any case, approaches that interfere with the conventional soldier postures are discouraged. Proposers must quantify how much information they expect their end-to-end telehaptic communication systems would be able to carry relative to standard military hand signal vocabularies.

Proposed research in the initial phase of this effort should focus on ergonomic, psychophysical, and information theoretic design aspects. For example, optimal device placement, size of the haptic communication channel, communication bandwidth requirements, and human attention constraints are all critical design principles to be addressed. Proposers must indicate whether human subject experiments are to be performed and how they will comply with government regulations and protocol. The later phase will involve the development and testing of a prototype HAPTAC system.

PHASE I: Investigate viability and design approaches of tactical telehaptic communication technology. Evaluate potential benefit to military operations and commercial applications.

PHASE II: Apply Phase I results, data, and analysis to develop a prototype that demonstrates the efficacy of HAPTAC technology. Validate through experimentation. Evaluate the performance of prototype through human subject experimentation.

PHASE III: HAPTAC technology would provide enhanced communication capability for dismounted soldiers, and may be particularly effective for special operations when stealth is required. It would also support commercial efforts in telehaptic technology, especially in the areas of mobile communications, virtual reality, telemedicine, video games, and distributed collaboration.

REFERENCES:
1. Katz, D., The World of Touch. Hillsdale, NJ: Erlbaum, 1989.

2. Cholewiak, R. W., Brill, J. C., and Schwab, A. “Vibrotactile Localization on the Abdomen: Effects of Place and Space.” Perception & Psychophysics, Vol. 66 No. 6, Aug 2004: 970-87.

3. Eimer, M., Forster, B., and Vibell, J. “Cutaneous Saltation Within and Across Arms: A New Measure of the Saltation Illusion in Soamatosensation.” Perception & Psychophysics, Vol. 67 No. 3 Apr 2005: 458-68.

4. K. Boff, L. Kaufman, and J. Thomas, Boff, K., Kaufman, L., and Thomas, J. (Eds.). Handbook of Perception and Human Performance. New York: Wiley and Sons, 2005.

5. Oakley, I., Kim, Y., Lee, J., and Ryu, J. “Determining the Feasibility of Forearm Mounted Vibrotactile Displays,” Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems (HAPTICS'06), 2006: pp. 8.

KEYWORDS: Haptics, Telehaptic Communication

SB082-026 TITLE: Open Source Information Tactical Exploitation (ONSITE)

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop novel natural language processing algorithms to support tactical warfighter applications.

DESCRIPTION: Natural Language Processing (NLP) research is concerned, broadly speaking, with the automated extraction or attribution of semantic content for text, often through exploitation of its syntactic properties. Traditionally, the objective of an NLP system is to organize the content of large text corpora for efficient retrieval and analysis. In this context, the organizational concepts (for, e.g., entities, categories, topics, relations) that NLP systems employ are designed to support retrieval and analysis at the strategic level. In addition, the principal operational concerns for these systems are accuracy (e.g., precision and recall) and scalability to multiple processors for large data volumes.

DARPA seeks innovative approaches for text NLP for tactical applications, which have constrained computational resources, accelerated operational timelines, and specific intelligence objectives. Examples of tactical applications for which NLP would provide needed capability include: patrol mission planning, insurgent extraction, hostage rescue, and targeting. In these scenarios, text data from sources such as local newspapers, blogs, and press releases can bring to bear operationally specific and time-sensitive evidence. Further, warfighters may have only minutes (not hours or days) to process the data for key evidence that may result in tactical advantage, so speed along with accuracy is critical. As such, current approaches to NLP may have limited value to tactical military applications. Indeed, even when decoding performance is tractable (such as with Viterbi-based approaches), feature extraction for supervised techniques may itself be expensive, resulting in slow end-to-end performance of these systems. Further, although so-called “shallow” language processing techniques such as part of speech tagging, chunk parsing, and entity recognition are typically fast, thus suitable for large volume and time-sensitive processing, textual evidence desired by the warfighter may be contextual or relational in nature: rather than extract all mentions of an “explosive device,” which may result in a very large subset of documents, the warfighter may be looking for explosive devices in a particular region or to be detonated at a particular time. Similarly, the warfighter may seek information about a particular enemy target: instead of all mentions of the target, a narrowed search of any evidence that the target is in a particular region or city may be desired. In such cases, the semantic relations between entities of interest must be extracted. DARPA seeks fast algorithms and techniques for processing evidence from text to provide this tactical benefit. Successful proposals will identify realistic tactical domains and offer innovative NLP approaches that are accurate and scalable to large (>10 GB) datasets, but execute quickly (<15 minutes) only on a single mobile computing platform such as a notebook or ultraportable PC. The objective of this effort is not to reduce algorithm capability to match the processing capabilities of a mobile computing platform, but to develop new algorithms that deliver needed NLP capabilities for applications that by necessity must run on a platform with limited computational resources. Trainable systems that can be ported to multiple languages are of particular interest. Proposed research in the initial phase of this effort should focus on demonstrating, in a rigorously empirical and quantitative fashion, the capability of the offeror’s technical approach. Offerors must identify the tactical applications their approaches are intended to support and design experiments accordingly. Offerors must also clearly indicate the data sources they propose to use for development and testing, the classes/entities/relations/topics on which will they will concentrate, and metrics they will use to measure accuracy and speed.

PHASE I: Investigate viability and design approaches ONSITE technology. Validate through experimentation. Evaluate potential benefit to military operations and commercial applications.

PHASE II: Apply Phase I results, data, and analysis to develop a prototype that demonstrates the efficacy of ONSITE technology. Evaluate the performance of prototype through experimentation on operationally realistic data.

PHASE III: ONSITE technology will provide enhanced content discovery and management capabilities for both military and commercial organizations.

REFERENCES:
1. Zhai Chengxiang, “Fast Statistical Parsing of Noun Phrases for Document Indexing,” In: Proceedings of the fifth conference on applied natural language processing, USA: 1997. 312-319.

2. Collin F. Baker, Charles J. Fillmore, and John B. Lowe, “The Berkeley FrameNet Project,” In Proceedings of the COLING-ACL, 1998: 86-90.

3. Daniel Gildea and Daniel Jurafsky, “Automatic Labeling of Semantic Roles,” Technical Report TR-01-005, International Computer Science Institute, Berkeley, 2001.

4. Cynthia A. Thompson, Roger Levy, and Christopher D. Manning, “Efficient Support Vector Classifiers for Named Entity Recognition,” In Proceedings of 19th International Conference on Computational Linguistics, 2002: 1-7.

5. Taku Kudo and Yuji Matsumoto, “Fast Methods for Kernel Based Text Analysis,” In Proceedings of the 41st Annual Meeting on Association for Computational Linguistics - Volume 1, 2003: 24-31.

KEYWORDS: Natural Language Processing, Entity Extraction, Relational Recognition, Document Classification, Topic Analysis

SB082-027 TITLE: Dismount Tracking in Urban Scenes

TECHNOLOGY AREAS: Ground/Sea Vehicles, Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop new methods for detection and tracking of multiple moving dismounts in aerial videos of busy, complex scenes such as urban areas. The methods should handle a large class of wide area video sensors including those with low resolution, low frame rates, with the ability to track dismounts in crowded conditions, and with extended occlusions.

DESCRIPTION: Wide-area video sensors can collect huge volumes of video of extended areas, but they are limited in resolution and frame rate. Dismounts are difficult to detect and track in aerial video because of few pixels on target, erratic (non-Kalman "non-linear" in nature) motion, low frame rates, grouping behaviors and crowded conditions, and extended occlusions in urban areas. Current methods can fail when even one of these factors is present. DARPA is soliciting novel methods for simultaneously tracking multiple dismounts that address these challenges while maintaining reasonable computational complexity. Following decades of research investment, tracking technology is relatively robust for vehicles on open roads with little or no clutter. While advances are being made for semi-urban and urban conditions, it is likely that incremental extensions to existing methods will not solve the difficulties presented by urban conditions, particularly for dismounts. Instead, significant leaps in capability are sought that employ non-traditional techniques such as knowledge-based reasoning, the use of context, and the fusion of video segmentation and tracking.

The developed algorithms should be able to detect and track an arbitrary number of dismounts across a range of speeds from a slow walk to a full sprint. The methods should be robust across camera viewpoints ranging from nadir to highly oblique, and across the full range of sun angles.

If successful, the developed algorithms will enable a significant advance in the detection and monitoring of dismount activities, and interactions with vehicles, buildings and locations of interest.

PHASE I: Develop initial dismount tracking formulation. Perform initial feasibility study comparing the new approach to current multi-object trackers.

PHASE II: Develop and refine the tracking algorithms. Perform more extensive comparisons to evaluate the performance of the method vs. current trackers on significant data sets.

PHASE III: Candidate applications include automation monitoring of both military and civilian borders and automation of security surveillance for events (civilian sector/homeland security).

REFERENCES:
1. Mittal, A. and Davis, L. S., “M2Tracker: A Multi-View Approach to Segmenting and Tracking People in a Cluttered Scene,” International Journal of Computer Vision, Springer Netherlands. Volume 51, Number 3 / February, 2003, pp 189-203.

2. Ramanan, D. and Forsyth, D., “Finding and Tracking People from the Bottom Up”, Proceedings of the 2003 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 18-20 June 2003, Volume: 2, On page(s): II-467- II-474 vol.2.

KEYWORDS: Image Registration, Parallax, Real Time, Tracking, Wide-Area Video Sensor, Dismount

SB082-028 TITLE: High Resolution 3D Reconstruction from Wide-Area Video

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: N/A

OBJECTIVE: Utilize modern wide area video sensors to create highly accurate 3D models of the area under surveillance with a goal to create models with voxel sizes one-half of the sensor fundamental ground sample distance.

DESCRIPTION: Emerging wide-area video sensors have the ability to cover large areas at high resolution. For example, the giga-pixel sensor being developed by the Autonomous Ground Ubiquitous Real-time Surveillance – Imaging System (ARGUS-IS) will be capable of imaging over 20 square kilometers at a ground sample distance (GSD) of 10 cm. Emerging super-resolution techniques provide the potential for multiple frames of data to be combined together to further reduce the ground sample distance. By taking observations from multiple perspectives, the fundamental imagery data exists for performing stereographic reconstructions of the area under surveillance. These sensors and systems offer the potential of being able to provide data for 3D model constructions over wide areas in short periods of time. There are a significant number of challenges to making this a reality. These include computational efficiency, algorithms appropriately designed to process data generated from focal plane arrays with rolling shutters, determining requirements for being able to effectively and efficiently generate super resolution data from wide field of view (60 degree field of view) sensors, as well as requirements for data collection in order to be able to generate 3D data of a given quality across the field of view.

PHASE I: Feasibility study to identify computational efficient methods for being able to perform 3D reconstructions across wide field of view electro-optic sensors including effects of rolling shutter focal plane arrays.

PHASE II: Implement computational efficient 3D reconstruction algorithms for wide field of view, ARGUS-IS, like system. Algorithms are to run on ground based equipment.

PHASE III: The technology developed under this SBIR has homeland security applications such as border surveillance as well as other applications that would use 3D models generated from airborne data.

REFERENCES:
1. Barrett, E.; Tyler, D. W.; Payton, P. M.; Ip, K.; Christie, D.N.; “New approaches to image super-resolution beyond the diffraction limit,” Unconventional Imaging III. Edited by Dolne, Jean J.; Gamiz, Victor L.; Idell, Paul S. Proceedings of the SPIE, Volume 6712, pp. 67120D (2007).

2. Mouragnon, E.; Dekeyser, F.; Sayd, P.; Lhuillier, M.; Dhome, M., “Real Time Localization and 3D Reconstruction,” 2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Publication Date: 17-22 June 2006, Volume: 1, on page(s): 363- 370.

3. Grossmanna, E.; Santos-Victorb, J., “Least-squares 3D reconstruction from one or more views and geometric clues,” Computer Vision and Image Understanding, Volume 99, Issue 2, August 2005, Pages 151-174.

KEYWORDS: Super-Resolution, 3D Reconstruction, Wide Field of View

SB082-029 TITLE: Detecting and Tracking Multiple Moving Objects from a Moving Platform

TECHNOLOGY AREAS: Air Platform, Information Systems, Ground/Sea Vehicles

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop new methods to detect and track dismounts and other moving objects near a mobile robot, using video sensors. The methods should operate in real-time while the robot is moving, and track all movers that are close enough to interact with or engage the robot.

DESCRIPTION: Ground robots are gaining importance in military operations, and are a significant part of Future Combat Systems for such missions as scouting and patrols, transport and logistics, and hazardous duties. Currently deployed robots such as Packbot have essentially no autonomy and must be directly controlled by operators. For ground robots to become a member of a squad, they need to operate among multiple moving objects (e.g. the human members of the squad), in unstructured environments (e.g. through bushes and trees). In order to coordinate their motion with the rest of the squad, they therefore need to detect and track multiple moving objects in the nearby environment, and predict future trajectories. This detection and tracking component must be robust despite the robot's own motion (possibly very shaky), and despite the objects being often occluded and only partially visible. This SBIR topic is seeking new perception algorithms for analyzing streaming video and/or ladar. To improve the utility and widespread deployment of robots, they must become more automated without compromising the safety of those around them. Existing systems are not capable of reliably detecting and tracking dismounts and other moving objects, particularly using passive sensors such as video.

New methods are sought that can detect moving dismounts and other moving objects from video sensors mounted on a moving robot, in real-time and at a sufficient distance such that the robot can stop or change course if collision is imminent. Recently, significant progress has been made in methods for detecting humans in single images [1]. As these methods generally rely on detecting silhouettes, they may suffer poor performance in military scenarios where soldiers wear camouflage uniforms. Processing multiple frames of video may be one way to help [2], but camera motion must be taken into account in the robotic domain. Incorporating scene classification and understanding may be another method for improving detection performance [3].

Accurate tracking is required for moving dismounts near the robot so that path planning can account for predicted trajectories. Tracking is straightforward when dismounts are detected reliably and well-separated from each other, and occlusions are brief. However, in typical conditions groups of dismounts are very common, and occlusions can last for many seconds. Recent advances in tracking have begun to address these issues [4] [5] but have not yet attained the accuracy required for operations, and usually assume a static or distant camera. The proposed methods should be able to track individuals in groups, through occlusions, and through move-stop-move conditions while the camera is moving.

PHASE I: Develop initial methods for detecting and tracking moving dismounts and other moving objects from a moving video camera mounted on a robot. Perform initial feasibility studies to estimate the scalability and accuracy of the approach.

PHASE II: Extend and refine the initial methods to track individuals and other moving objects in groups and through occlusions under realistic conditions. Compare with alternative approaches to demonstrate improved utility on large, realistic data sets. Integrate the developed tools into an existing robotic demonstration platform.

PHASE III: The algorithms developed under this topic are applicable to both military and civilian. In the Unmanned Air and Ground Vehicle areas, these algorithms can be used to enable systems to detect other moving objects in order to prevent collisions. These can also be used in a similar manner in the commercial automotive industry to enable safe semi-autonomous driving.

REFERENCES:

1. N. Dalal and B. Triggs. “Histograms of Oriented Gradients for Human Detection.” In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 2005.

2. P. Viola, M. J. Jones, and D. Snow. “Detecting pedestrians using patterns of motion and appearance.” In Proceedings of the IEEE International Conference on Computer Vision, volume 2, pages 734–741, 2003.

3. Derek Hoiem, Alexei A. Efros and Martial Hebert. “Putting Objects in Perspective.” In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, volume 2, pages 2137-2144, 2006.

4. Tao Zhao and Ram Nevatia. “Tracking Multiple Humans in Complex Situations.” IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 26, issue 9, pages 1208-1221, 2004.

5. A.G.A. Perera, C. Srinivas, A. Hoogs, G. Brooksby and W. Hu. "Multi-Object Tracking Through Simultaneous Long Occlusions and Split-Merge Conditions." In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, volume 26, issue 9, pages 1208-21, 2006.

KEYWORDS: Moving Object Detection, Tracking, Group Tracking, Collision Avoidance, Robotic Vision

SB082-030 TITLE: Path Planner for Dynamic Environments

TECHNOLOGY AREAS: Air Platform, Information Systems, Ground/Sea Vehicles

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop algorithms for planning paths through dynamic, GPS-denied environments, using realistic models for sensor processing on unmanned ground and air vehicles.

DESCRIPTION: At the core of control systems for autonomous vehicles is a path planner (PP). The PP accepts as input (i) a model of the current state of the environment, (ii) the current location of the vehicle in that environment, and (iii) the location of the goal point. As output, the PP produces a path from the current position to the goal point which optimizes an objective function. An example of an objective function is the cumulative cost of path traversal.

Current state of the art and why it does not meet current requirements:
Many currently deployed autonomous systems use a PP which assumes a static environment. See [1], for example. In many of these systems, the environment is represented as a 2½-D grid with each grid cell labeled with its cost of traversal. There is no explicit representation of a discrete "object"; hence, it is difficult to encode the future trajectory of a moving object. Furthermore, the vehicle's current location in the environment is usually dependent on GPS, so that performance degrades rapidly when GPS signals are not available.

What research can be drawn on and what is the desired outcome of this SBIR: In order for autonomous systems to operate in militarily relevant, dynamic environments, it is necessary to develop a PP which accounts for moving objects, and plans paths which evade objects which are on a collision course. There has been a lot of work done on developing efficient path planners in the academic community. See [2] and [3], for example. This SBIR topic is focused on designing and developing a PP which will enable an autonomous vehicle with onboard sensors to navigate in militarily relevant environments. In particular, DARPA is seeking a PP with the following characteristics:
1. Uncertainty: The PP must be able to generate good paths even when the relative locations and trajectories of objects are only known approximately. This uncertainty is a result of limitations of the onboard sensors and sensor data processing. For example, camera-based sensors can often estimate range information with errors no better than 5%, and only out to a limited distance.
2. Realistic representation: The PP must operate on a model of the environment which could realistically be inferred using common on-board sensors and sensor processing algorithms. DARPA is not interested in a PP which requires unrealistically accurate or complete knowledge of objects' relative sizes and/or positions.
3. No GPS: The PP must be able to operate in regions with no GPS coverage. This implies that the PP must be able to operate on representations in relative rather than absolute coordinates. In addition, an important criterion is selecting a path which can easily be executed without GPS. For example, it may be preferable to choose a longer path which stays within view of trackable landmarks, rather than a shorter path which is devoid of such beacons.
4. Efficiency: The PP needs to be able to compute a plan very efficiently. In addition, it needs to be able to adapt an existing plan to take into account a newly discovered object. Such re-planning should not require starting the planning process from scratch each time.

PHASE I: Design an algorithm for planning paths through dynamic, GPS-denied environments, using realistic simulated models of the environment. Perform a study to illustrate the feasibility of the approach.

PHASE II: Based on the results of Phase I, build a proof-of-principle prototype. The prototype must run in real-time on both simulated and real sensor data.

PHASE III: A successful approach will have significant impact on a number of areas. For example, in the Unmanned Air Vehicle and Unmanned Ground Vehicle areas, these algorithms can be used to enable systems to plan collision-free paths in dynamic environments such as urban terrain. In the commercial automotive industry, these algorithms can be used to enable autonomous or semi-autonomous driving on roadways. Commercial applications of the technology also include path planners for autonomous household vehicles.

REFERENCES:
1. Kelly, Stentz, Amidi, Bode, Bradley, Diaz-Calderon, Happold, Herman, Mandelbaum, Pilarski, Rander, Thayer, Vallidis, Warner: Toward Reliable Off Road Autonomous Vehicles Operating in Challenging Environments. I. J. Robotic Res. 25(5-6): 449-483 (2006).

2. [Lato91] J.C. Latombe, Robot Motion Planning, Kluwer Academic Publishers, Norwell, Mass. 1991.

3. Anthony Stentz: Optimal and Efficient Path Planning for Partially-Known Environments. International Conference on Robotics and Automation (ICRA) 1994: 3310-3317.

4. Likhachev, D. Ferguson, G. Gordon, A. Stentz, S. Thrun, Anytime Dynamic A*: An anytime, replanning algorithm, in: Proceedings of the International Conference on Automated Planning and Scheduling (ICAPS), 2005.

5. Likhachev, D. Ferguson, G. Gordon, A. Stentz, and S. Thrun: Anytime Search in Large, Dynamic Graphs. Artificial Intelligence Journal (AIJ), (to appear).

KEYWORDS: Path Planning in Dynamic, Uncertain, GPS-Denied Environments; Autonomous Navigation

SB082-031 TITLE: Activity Models for Robots

TECHNOLOGY AREAS: Information Systems, Ground/Sea Vehicles

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop new methods that improve the efficiency of building models of human-robot group activity through the use of human instruction. The methods should take advantage of feedback and interaction between human and robot, in a relevant visual problem domain such as robotic navigation, transport and interaction within a group of soldiers.

DESCRIPTION: Robots such as Big Dog are becoming increasingly capable of providing basic services to soldiers in the field, such as transport of equipment and supplies on missions in difficult terrain where large vehicles are impractical or undesirable. A major technical barrier preventing the deployment of such assistant robots is the difficulty of programming and training a robot to assume a certain role in a group activity. A robot must know what is happening around it in order to act and react properly to changing circumstances. Currently, however, robots are programmed for very specific tasks in constrained environments, while teaching a robot a new task or behavior requires highly specialized technical knowledge. Furthermore, robots cannot react adequately to the dynamic, unstructured conditions usually found in operational areas because robotic understanding of the surrounding environment and activities is very limited.

Overcoming these challenges will require a significant advance in robotic perception and environmental understanding. A robot must have knowledge of human activities that may happen nearby given the current context, and its own role in those activities. It must have representations for its tasks that are consistent with these activity models to enable adaptive reasoning and planning. Additionally, it must do this under the partial and inaccurate information obtained from its sensors. DARPA is seeking new approaches that combine human instruction and computer vision to efficiently and intuitively teach a robot how to build a model of, and subsequently recognize, human activities surrounding it from video cameras mounted on the robot. Statistical learning methods typically require substantial amounts of training data to achieve robustness, but human instruction can be used to compensate for the small training sets that would typically be available for realistic scenarios. The learning and recognition of human behavior, both individuals and groups, in video has advanced considerably in the past few years, but further advances must be made in order to achieve robustness under the difficulties presented by video from a mobile ground robot, such as missing, fragmented and erroneous tracks.

The resulting system would enable a robot to safely interact with soldiers so that the robot becomes a significant asset to the group, and is never a liability. Example activities and scenarios of interest include group marching along a path, rapidly responding to an ambush or attack, and a coordinated attack on an enemy position.

PHASE I: Develop an initial formulation for using human instruction to significantly improve the efficiency of building a model of group activity and subsequent recognition from robot video data. Demonstrate the feasibility of the approach by comparing methods with and without human instruction.

PHASE II: Implement, expand and refine the initial formulation. Compare with standard activity recognition methods on large, realistic data sets. Integrate the developed tools into an existing robotic demonstration platform.

PHASE III: The algorithms developed under this topic are applicable to both military and civilian needs. In the Unmanned Ground Vehicle area, these algorithms can be used to enable systems to participate alongside humans as full members of a group activity. In the commercial automotive industry, these algorithms can be used to enable autonomous or semi-autonomous driving on roadways, obeying the rules of the road.

REFERENCES:
1. Michael T. Chan, Anthony Hoogs, Zhaohui Sun, John Schmiederer, Rahul Bhotika and Gianfranco Doretto. "Event Recognition with Fragmented Object Tracks," Proceedings of the 18th International Conference on Pattern Recognition, 2006. IEEE.

2. S. Hongeng, R. Nevatia and F. Bremond. "Video-based event recognition: activity representation and probabilistic recognition methods." In Computer Vision and Image Understanding, 96:22, pp. 129-162, Nov. 2004.

3. S. Gong and T. Xiang. "Recognition of Group Activities using Dynamic Probabilistic Networks." In Proc. International Conference on Computer Vision, pp. 742-749, 2003.

KEYWORDS: Human Instruction, Robotic Vision, Group Activity Recognition

SB082-032 TITLE: Exposing Latent Information in Folksonomies for Reasoning

TECHNOLOGY AREAS: Information Systems, Human Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study for an approach and system that enables high level reasoning with folksonomy metadata (collections of words chosen from an unconstrained vocabulary) by using linguistic resources such as WordNet to instantiate the structures that are implicit in folksonomic tag data.

DESCRIPTION: Taxonomies impose a potentially useful organizational structure onto information but, as Shirky points out (Ref. 1), these structures are brittle, developed by experts, and typically subjective. Maier and Delcambre (Ref. 2) have done work on superimposing multiple structures onto data without requiring changes to the underlying data. While this helps address the subjectivity of classification schemes by permitting multiple taxonomies or schemas to be used for the same data, the research has focused on formal methods and relational databases.

The emergence of web sites that allow users to tag items such as images and URLs with keywords drawn from unconstrained vocabularies is a grass-roots response to users' desires to organize data according to their own subjective preferences. Similarly, though on a smaller scale, technical journals have included keywords for some time in order to provide readers with very succinct snapshots of articles and to facilitate the discovery of related articles. While in this latter case the keywords are frequently drawn from terms particular to the argot of the targeted community, they are nonetheless not formally constrained. As communities grow around tagged data, the users informally internalize and adopt many of the terms used by other members of the community and a "user-created bottom-up categorical structure […] with an emergent thesaurus" – that is, a folksonomy (Ref. 3) –emerges.

This categorical structure, while captured in the lexicon of the users, lacks both the hierarchical structure that a formal taxonomy would provide and the utility for reasoning that would come from having an ontology that describes the underlying data. However much of this structure is still there and accessible to humans because the tags are words that have intrinsic meaning, synonyms, and associations and the structure is implicit in the language. If computers are to be able to exploit this information it must be made explicit. Resources like WordNet (Ref. 4), Propbank (Ref. 5), and FrameNet (Ref. 6) provide information about relationships in the language that can be used to extract and construct an explicit representation however a great deal of work will be required to exploit this in the context of ill-defined communities employing unconstrained tagging vocabularies.

This topic seeks proposals to develop a system that identifies and exposes taxonomic and onto logic structure that is latent in the folksonomic tags used in open, publicly available sites such as Google Image Labeler (http://images.google.com/imagelabeler) and demonstrates the ability to perform higher order processing of this data using the induced structure.

PHASE I: Prepare a feasibility study for a system to couple linguistic tools with folksonomically classified data in order to induce and expose additional structure in the folksonomic classification schema. During the first phase the performer will identify the resource needed, approaches to be taken for making latent structure explicit, and candidate applications that can be used to demonstrate the system. A preliminary design review will be conducted and a formal report created that documents the design decisions and expected limitations of a system. As a part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized and a prototype constructed that demonstrates the successful operation of the system using real-world data.

PHASE III: There are possible applications for this technology to both military and commercial problems. While some commercial sites enable users to tag content to ease subsequent location and retrieval, and other sites use folksonomic tagging to facilitate the location of similar content, there is no richer structure available for automated exploitation within and across sites. Within the DoD, situational awareness efforts would benefit from these technologies as well as open source analysis tasks.

REFERENCES:

1. http://shirky.com/writings/ontology_overrated.html

2. Models for Superimposed Information, D. Maier and L. Delcambre, Workshop on Conceptual Models for the WWW in conjunction with the International Conference on Conceptual Modeling, (ER '99), November, 1999, Paris, France, Lecture Notes in Computer Science 1727, Springer Verlag, 1999, pp 264-280.

3. "Folksonomy coinage and definition". http://vanderwal.net/folksonomy.html

4. http://wordnet.princeton.edu/

5. http://www.ldc.upenn.edu/Catalog/CatalogEntry.jsp?catalogId=LDC2004T14

6. http://framenet.icsi.berkeley.edu/

7. "Toward a Social Semantic Web," A. Mikroyannidis, Computer 40(11), Nov 2007.

8. http://en.wikipedia.org/wiki/Intellipedia

9. "The structure and form of folksonomy tags: The road to the public library catalog" Spiteri, L.F. Information Technology and Libraries (2007).

KEYWORDS: Folksonomy, Ontology, Taxonomy, Web 2.0, Tagging.

SB082-033 TITLE: Hardware Independent Networked Active Sensor Middleware

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study to develop a hardware independent software package to provide a low power active wireless sensor network with middleware services resulting in a quantitative improvement in detection capabilities and power consumption.

DESCRIPTION: Wireless sensor networks, are in a phase of rapid development, and as such, software to support existing and planned hardware systems often lags behind in terms of maturity (specifically hardware independence). Integration of hardware and software design is critical [1] if low-power consumption and high probability of detection (Pd) are to be achieved. This is especially true for Active Sensors Networks as the vast majority of low-power wireless sensor networks employ a passive detection modality [2]. Given the rate at which hardware improves, end users are understandably hesitant to invest in software packages which would be obsolete in a short period of time. In order to exploit network gain from a field of wireless active sensors, information must be shared between local groups of sensors, and processed to improve detection performance. Detection of signals within noise for these types of active sensors is a well studied problem. It is also well known that gains can be made by combining information from multiple sensors. Improved detection performance is not limited to Pd, but also encompasses classification, localization and tracking. Reduction of power consumption is obtained by careful balancing of wakeup rates, transmission periods (both communications and detection transmissions), periods of reception (in the multi-static case) and expected target velocities. Software packages that fully exploit a hardware presentation layer for both the sensor and Media Access Control (MAC) physical layers, as well as present a standardized application programming interface (API) to the signal and information processing layer are needed. This topic hopes to develop a software standard which would support current and future wireless active sensor networks, and thereby protect investments in information and signal processing application software. Active sensors can include Acoustic Echo-Location as well as RADAR, or any other active detection medium. Both mono-static and multi-static modalities should be supportable by the middleware, as well as the possibility that the device may or may not support inter-node communication via the detection medium.

PHASE I: Prepare a feasibility study. During the first phase, the performer will propose a conceptual software design. Formal design will be performed and a preliminary design review and report will be generated. As part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized. All appropriate engineering testing and validation of design issues will be performed. A critical design review will be performed to finalize the design, and prototype code written and tested on a PC running an emulation of an active network.

PHASE III: Candidate applications for this technology span both the military and commercial arenas. In general terms, the middleware developed will be used in multiple forms of wireless sensor networks exploiting the superior detection capabilities of active modalities under many circumstances. Cheap low-power active sensor devices can be easily deployed, and represent the state of the art in detection capabilities. The greater range of detection and low false alarm rates of active sensors verses traditional passive sensors insures that this technology will find multiple uses in both military and commercial markets.

REFERENCES:

1. Romer, K; Mattern, F., "The Design Space of Wireless Sensor Networks," Wireless Communication, IEEE, Vol. 11, Issue 6, Dec 2004: pp. 54-61.

2. Dutta, Prabal; Grimmer, Mike; et.al., "Design of a Wireless Sensor Network Platform for Detecting Rare, Random, and Ephemeral Events," Proceedings of the 4th International Symposium on Information Processing in Sensor Networks (IPSN), April 24-27, 2005: Article Number 70.

KEYWORDS: Wireless, Network, Active, Sensor, Independent, and Middleware

SB082-034 TITLE: Wireless Connectivity for Streaming Video

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Weapons

ACQUISITION PROGRAM: N/A

OBJECTIVE: The end goal of this SBIR is to produce a small number of gigahertz band, high-bandwidth, wireless connectivity devices, demonstrating high-quality, low-latency, streaming video. These devices will be man-portable, self powered and capable of being camouflaged. They will enable easy interface to standard military communications and video hardware and will provide low power, low latency, high quality, video transmission capabilities. These capabilities could be used for streaming video of remote video/IR sensors for operator's surveillance and weapon's sighting systems on ground, airborne and maritime platforms, as well as for remote control of robotic platforms.

DESCRIPTION: The need to stream real time video to remote locations has been established by the warfighter as they deploy the tools of the trade which include: sensors for surveillance and operational security and remote controlled robotic platforms.

Specifically, in a weapon sighting system, there is the desire to create real time video transmission connectivity with zero latency, and no wires. Then, there is the added dimension of using the same wireless connectivity for surveillance supporting multiple objectives simultaneously. Within the robotics domain, the desire is to maintain low latency real time video to robot platforms for the purposes of steering and targeting through circuitous caves and urban canyons.

To meet these operator driven needs, the Phase I tasks will include studying all applicable available Wireless Connectivity technologies to determine the pipe/Bandwidth, otherwise known as Through-put, for achieving real time streaming video in self powered, field-able gear, as well as systems in development. These systems will be screened for their applicability to providing small, low power, light weight, multi-hopping video streaming capabilities.

Currently, there is streaming video available for use in vehicles and satellites which has the bandwidth and power to stream real time video via wireless connectivity, but they are bulky and consume too much power. In the field, at the operator’s level, there is no ability to accomplish this desired task, in man-portable, low power, mil-spec equipment, such as weapon sighting systems, real time surveillance sensors or robotic guidance systems.

The problem in creating a wireless man-portable connectivity is the integration of 20-40 Gigahertz frequency components, which will provide a low power, high resolution, and high bandwidth link with more than 1Mbps.

Bluetooth with its low power, frequency hopping 1MHz band has been shown to stream VHS type (low) quality video, but its limited range eliminates it from consideration for the missions at hand. 802.11 technologies have long shown the ability to stream video of various qualities, but they are power hungry, and lack frequency hopping stealthy-ness.

Other technical formats exist which can move real time streaming video in the desired bandwidth/pipe. Up in the Gigahertz spectrum there are multiple solutions which can accommodate the ability to achieve high data rate, streaming video. The technology was developed for use in radar applications (1).

The RF connectivity currently being used for wireless connectivity is in the MegaHertz (MHz) band; (i.e., such as FM), does not employ frequency hopping, and as such can be directionally found (DF) which is NOT acceptable for operational deployment.

A GHz (Gigahertz) band solution offers the potential to stream real time video, all the while frequency hopping to achieve stealthy-ness and connectivity for wireless streaming video. To the DF equipment, the signature looks like white noise, and cannot be triangulated, which is desired by warfighters.

State of the art for this Gigahertz solution is that there are very few companies who have created the chipsets (commercial or otherwise) for use by military operators.

Therefore, the goal of this SBIR R&D will be to bring about the detailed use of the Gigahertz wireless connectivity by creating a functional, wireless, real time, multi-hopping streaming video system on a small low power platform. This platform would be applicable to weapons sighting platforms, surveillance systems, and robotic platforms.

PHASE I: Prepare a feasibility study for a Wireless Connectivity for Streaming Real-time Video concept. During the first phase, the performer will propose a conceptual wireless connectivity in the Gigahertz spectrum for use in a man-portable CPU driven, weapons sighting, surveillance platform to prove out the total capability of this wireless capability technology. Formal design of the concept will be performed and a preliminary design review and report will be generated. As part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized. All appropriate engineering testing and validation of design issues will be performed. A critical design review will be performed to finalize the design and a prototype 2 unit system will be manufactured and tested.

PHASE III DUAL USE APPLICATIONS: Candidate applications for this technology span both the military and commercial arenas. In general terms, the hardware developed could be used for any sort of ad hoc data transmission. There will be the military's definite use of this wireless connectivity, so too Law enforcement as well, as in various security applications in the public sector. Commercially there will be uses for streaming real time video on man-portable devices, which can be supported by the larger bandwidth of the Gigahertz solution, as well as Homeland Security applications like perimeter control and robotic bomb disposal.

REFERENCES:
1. "RF Cafe: Ultra Wideband (UWB) Websites," RF Cafe, http://www.rfcafe.com/references/resources/ultra_wideband.htm.

2. "UWB simplifies portable design," EE Times, http://www.eetimes.com/showArticle.jhtml?articleID=16506167

3. "The Source for Ultra-wideband Business and Technology," http://www.ultrawidebandplanet.com/

KEYWORDS: Wireless; Man-Portable CPU, Weapon Sighting System, Streaming Real-Time Video, Gigahertz Frequency, Self Powered, UWB, HUD

SB082-035 TITLE: High Accuracy, Non-GPS Pose Estimation and Real-Time Depth Sensing

TECHNOLOGY AREAS: Sensors, Electronics, Human Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: To develop a soldier-worn means of estimating the location and orientation of an infantryman's head and weapon to a high degree of accuracy in order to support augmented and mixed reality applications without external sensor infrastructures and to develop algorithms to perform real-time depth sensing and occlusion mapping with visual-only systems at distances up to 300 meters. In this case, pose estimation refers to the location and orientation of an infantryman's head and his weapon. The depth-sensing must be accurate to 5% of the distance between the observer and the synthetic object.

DESCRIPTION: Allowing infantrymen to train in the real world but enhancing that world will simultaneously make the training more effective while reducing the number of overhead personnel needed to conduct the training. With current laser engagement training technology, for instance, soldiers do not get to see tracers (theirs or the enemy's), the strike of the rounds, explosions, or other weapons effects. At combined arms training centers, personnel who speak foreign languages are used to make training for urban operations in those parts of the world more effective. Those foreign-speaking personnel, who are training overhead as they are not part of the training audience, are not easily available. With mixed reality, those training enablers could be used to support training in many geographically distant locations. A handful of real personnel acting as the inhabitants of a small village could be multiplied through the use of mixed reality to look like a fully inhabited village.

Mixed reality is not a new concept. Several attempts have been made to build such systems [1, 3, 5, 6, and 7]. These systems typically train only a handful of soldiers, and require extensive and expensive infrastructure. Many of these systems require the user to remain in a fixed location; although, he can look around. Others allow the trainee to be "untethered," but work in a small number of rooms, perhaps just one, and require extensive instrumentation and infrastructure [1, 3, and 4]. Often they also require the trainee to wear special equipment to help the system track the location, orientation, and pose of each real actor in the scene. These limitations of current technology make it impractical to train platoons and companies in the real world.

One of the key technology gaps that make mixed reality impractical today is the ability to accurately locate the trainee in the world. If such a system determines the wrong rifle orientation by as little as .091 degrees, a simulated shot would completely miss a man-sized target at 300 meters distance. Being wrong by as little as four centimeters can result in rendered images coming through walls instead of doors. To make implementation practical, such a technology would need the potential to be completely soldier-worn, require no special markers to be worn, and be infrastructure free. "Infrastructure free" means that there are no external sensors, such as cameras, that must be deployed in the training area; although, it does permit the presence of a communication infrastructure between the soldier-worn systems and a server that provides the synthetic entities and effects to be displayed to the live trainee. The identification of this technology would point the way toward implementation of a practical, infrastructure-free mixed reality system for deployed and home-station training.

Another of the key technology gaps that make mixed reality impractical today is the ability to do real-time depth sensing and occlusion mapping. When viewing a scene in the real world, humans know that one object is in front of another because it partially occludes the other. In virtual environments, where ground truth is known, occlusion mapping is merely a matter of math. In a mixed-reality environment, with soldier-word systems, occlusion mapping requires the system to sense the depth of objects in the scene and compare those depths against the "known" depths of the synthetic objects. Then it can render only those parts of the synthetic objects that are not occluded by real ones. In mixed-reality environments with static objects, occlusion mapping can be based on an a priori model of the environment. In a realistic environment, however, there will be many dynamic, moving real objects mixed with the synthetic objects. Depth sensing and occlusion mapping must be done continuously and quickly.

Because such a system would be soldier-worn, the proposal must make explicit assumptions about the size, weight, power consumption, number and types of sensors, and computational requirements of the system on which the developed algorithms would be expected to run.

PHASE I: Feasibility study to identify technologies for accurate, infrastructure-free pose estimation. The algorithms should determine the location of both a soldier and his weapon to within four centimeters and the orientation of both a soldier and his weapon to within 100 micro-radians. Develop and demonstrate technologies for accurate, infrastructure-free depth sensing and occlusion mapping. The effort should identify technologies that will allow the time between sensing of dynamic objects in the scene and rendering properly occluded synthetic objects in less than 5 milliseconds. The technology must maintain this level of accuracy even if objects in the scene are moving up to 20 miles per hour, but with a stationary observer. The developed algorithms must be capable of working in day and night conditions.

PHASE II: Implement the solution in a proof-of-principal. Demonstrate the accuracy required under the conditions described. Demonstrate how this implementation supports the rendering of synthetic objects in the real world (e.g., through optical-see-through goggles) with a frame rate of at least 30 frames per second, with less than a 1 pixel image jitter. The proof of principal should support the insertion of dynamically generated synthetic objects that appear to be located in the real scene. Demonstrate the depth-sensing accuracy required within the 5 millisecond timeframe. Demonstrate how this implementation supports the rendering of synthetic objects in the real world (e.g., through optical-see-through goggles) with a frame rate of at least 60 frames per second, with less than a 1 pixel image jitter. The proof of principal should support the insertion of dynamically generated synthetic objects that appear to be located in the real scene. This demonstration need not support low lighting conditions, but it should be soldier worn.

PHASE III: Enhance the prototype from Phase II to low lighting conditions. Demonstrate simple interactions with synthetic entities, such as direct fire. Implement and demonstrate prototype applications of this technology for commercial applications, such as entertainment and training. For instance, an entertainment application might be standing in the middle of a field at Gettysburg and watching Picket's Charge occurring around you. A training application might be firefighters training in a training building battling synthetically-generated fire.

REFERENCES:
1. Dean, Frank S., Jr., et. al. "Mixed Reality: A Tool for Integrating Live, Virtual & Constructive Domains to Support Training Transformation," Proceedings of the 2004 Interservice/Industry Training, Simulation & Education Conference, Orlando, FL.

2. Ellis, Stephen R. (2006). "Towards Determination of Visual Requirements for Augmented Reality Displays and Virtual Environments for the Airport Tower," Proceedings of Virtual Media, West Point, NY, pp. 31-1 – 31-9.

3. Fuentes, G. (2007). "Ultimate Shoot House: Blend of live training and virtual technologies immerses U.S. Marines in the urban fight." Training & Simulation Journal (TSJ), 8(4), 3.

4. Luck, Jason P. et. al. (2002). "Development and Analysis of a Real-Time Human Motion Tracking System," Proceedings of the Sixth IEEE Workshop on Applications of Computer Vision: pp. 196-202.

5. Malo, Scott, et. al., "Going Beyond Reality: Creating Extreme Multi-Modal Mixed Reality for Training Simulation," Proceedings of the 2004 Interservice/Industry Training, Simulation & Education Conference, Orlando, FL.

6. NAVAIR Orlando (2006). Technical Report: DARTS I: Dismounted Augmented Reality Technology Testbed, Final Report.

7. Wursthorn, Sven, et. al. (2002). "Applications for Mixed Reality." 20th ISPRS (International Society for Photogrammetry and Remote Sensing) Congress, 2004: pp. 1049-1054.

KEYWORDS: Mixed Reality, Augmented Reality, Pose Estimation, Infantry, Training

SB082-036 TITLE: Capturing Insights from Firefights to Improve Training

TECHNOLOGY AREAS: Battlespace, Human Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: To conduct a study to determine what infantry soldiers learn in their first few firefights that increases their life expectancy in subsequent engagements, to determine the feasibility of exposing soldiers to these factors in training so they effectively experience their "first five firefights" prior to entering combat, and (in Phase II) to design a training system that leverages these insights.

DESCRIPTION: While existing literature points to factors that contribute to effectiveness in combat and the numbers of casualties, none of it answers the fundamental questions posed by this study. Is it true that a soldier has a significantly longer life expectancy after he has survived his first few firefights? If so, why is it true? What does the soldier learn in those first few firefights that makes the difference? Can that "something" be replicated, fully or in part, in training so that a soldier's life expectancy in those first few firefights is similar to a veteran? Finally if those things a soldier learns in his first few firefights can potentially be experienced in training, how might the Army and Marine Corps construct such a training experience?

BACKGROUND: It has long been asserted that an infantryman's life expectancy in combat can be measured in minutes, but that if he survives his first couple of firefights he is likely to live for months, and if he survives those months, he is likely to live to the end of his tour of duty. It has been demonstrated that units tend to suffer higher casualty rates in their first engagements with the enemy. Several studies exist that document this phenomenon for pilots and aircrews. In air combat over Vietnam, "forty percent of all pilot losses occurred in their first three engagements. However 90 percent of those who survived three engagements went on to complete a combat tour." [Scales, pp. 20-21].

A review of existing literature and informal interviews with veterans from Vietnam to Iraq suggests that causes of combat casualties are related to six factors: 1) ability to cope with sensory overload, 2) ability to overcome stress and fear, 3) ability to maintain unit cohesion, 4) confidence in unit leadership, 5) maintaining threat awareness, and 6) understanding the proper use and implications of terrain. Specifically, the factors can chain together when sensory overload and isolation lead to increased stress/fear which in turn can lead to higher casualties. These casualties may be mitigated by unit cohesion, confidence in leadership, awareness of threats and the proper use of terrain.

Studies "show that soldiers with a greater mental aptitude are more self-confident and are better able to deal with ambiguous and confusion situations." [Daddis, p. 23] Based on his analysis, Daddis asserts that "incorporating battlefield stimuli—the sights, sounds, and smells of a firefight—into training makes training real… Experiential learning is critical in sensitizing soldiers to the bedlam of combat. Leaders must create unpredictability in their training events yet allow failure among leaders and followers. Creating sensory chaos in training (chaos that often cannot be realized in simulation centers) can only be done by creating sensory chaos during training. Soldiers must train in situations where they can learn how they individually respond to stress and anxiety" [Daddis, p. 26]. After their first combat, among many combat veterans, a kind of depression sets in because "their first experience of combat had not turned out the way they had imagined it would. They were used to the orderly sham battles of field exercises; the real thing proved more chaotic and much less heroic than they had anticipated, and the mutilation caused by modern weapons came as a shock." [Kellet, p. 313] Spiszer also asserts that in training soldiers must be exposed to realistic "sights, sounds, smells and feelings of isolation and fear when they occur." [Spiszer, p. 69] Bradshaw asserts that all soldiers experience battlefield stress, but that tough training under realistic conditions can reduce battlefield stress. [Bradshaw, pp. 20-21] Researchers have asserted that battlefield stress and fear can lead to higher mental and physical casualties, but this can be mitigated. Describing the Israeli experiences in 1973, Belenky stated that "the battalion ranked as having the greatest stress (on the basis of preparation, type of battle, tactical and logistic support, and confidence in higher headquarters) had the highest number of physical casualties, the highest number of psychiatric casualties but that Israeli Defense Force soldiers from units with good leadership, good unit cohesion and who had stable personal and family lives were less likely than other soldiers to suffer combat-related psychiatric breakdown." [Belenky, p.30-32] In addition, Dave Grossman's book On Killing is replete with the costs entailed by the Army's expectation for the soldier to kill. He claims that the burden of killing is so great that "in many circumstances, soldiers on the battlefield will die before they can overcome" their intense resistance to killing another human being. A survey of wounded combat veterans in the European Theater during World War II is telling. Of the 277 soldiers interviewed, "65 percent of the men admitted having had at least one experience in combat in which they were unable to perform adequately because of intense fear." [Grossman] Researchers suggest that fear can be mitigated through good unit cohesion and confidence in their leadership.[Mitchell] Strong unit cohesion is important because "the contemporary battlefield also produces the anxiety of being alone. Reassurance from nearby mates, which strengthens resolve against the enemy and his weaponry, withers when friendly sights and sounds are absent." [Daddis, p. 24] Noy emphasized the importance of cohesion and asserts that a breakdown in cohesion is "the main, not secondary, cause of individual disorganization." [Noy, pp. 69-86] The claim can be made that this individual disorganization leads in increased stress which ultimately can lead to increased casualties. "Most interesting is the notion that individual training cannot itself mitigate the effects of fear but that "collective training must focus on mastering tactics, techniques, and procedures and understanding the human aspect of fighting within a group. A commander's goal should be to develop bonds that provide a sense of cohesion." [Daddis, p. 27] In addressing the debate about whether American soldiers are effective merely due to firepower and technology, Wong, et. al. stated that "The U.S. Army is the best in the world because, in addition to possessing the best equipment, its soldiers also have an unmatched level of trust. They trust each other because of the close interpersonal bonds between soldiers. They trust their leaders because their leaders have competently trained their units. And they trust the Army because, since the end of the draft, the Army has had to attract its members rather than conscripting them." [Wong, pp. 22-23] In posing the questions from Stouffer's classic study (of combat motivation from World War II) to Iraq War veterans, Wong noted that Iraqi soldiers were coerced into fighting and had poor unit cohesion, thus decisions to surrender were quite common. On the other hand, Wong noted that the U.S. soldiers most common reason for doing their best in combat was associated with cohesion, in effect fighting "for their buddies." [Wong, p. 10] Good leadership also has an important role in controlling fear and reducing casualties. "Leaders have a responsibility in training to understand and prepare for the human aspects of war, recognizing their soldiers' limits, needs, and motivations while remaining tactically and technically proficient, which is a tall order for younger officers. While they must manage their own fear in combat, they must also cope with subordinates' fears." [Daddis]

While the literature points to factors that contribute to effectiveness in combat and casualties, none of it answers the fundamental questions of this study. Is it true that a soldier has a significantly longer life expectancy after he has survived his first few firefights? If so, why is it true? What does the soldier learn in those first few firefights that makes the difference? Can that "something" be replicated, fully or in part, in training so that a soldier's life expectancy in those first few firefights is similar to a veteran? Finally if those things a soldier learns in his first few firefights can potentially be experienced in training, how might the Army and Marine Corps construct such a training experience?

PHASE I: Conduct a study to determine what infantry soldiers learn in their first few firefights that increases their life expectancy. Determine the primary factors that mitigate casualties from veterans who have experienced several firefights. Determine the feasibility of exposing soldiers to these lessons/factors in training so that they experience their "first five firefights" before going into combat. Determine the metrics that would be used to evaluate whether a training experience is "realistic" in the context of the relevant factors experienced in a soldier's "first five firefights." Identify technology gaps that need to be filled in order to build such a training system.

PHASE II: Design a training system that imparts the lessons/factors from the "first five firefights" in training to increase survivability for soldiers in their first combats. This includes building the architecture and conducting proofs of principle where technology exists. Finally, determine how to measure the training experience to determine how closely it replicates the lessons of the first few firefights.

PHASE III DUAL USE APPLICATIONS: Candidate applications for this technology span multiple military and civilian training areas. Any of the branches of the military will find this new training approach to be valuable and necessary. Additionally this training has applications for Homeland Defense.

REFERENCES

1. Scales, Robert H., Certain Victory, Washington: Brassey's, 1994, pp. 20-21.

2. MAJ Gregory Daddis, "Understanding Fear's Effect on Unit Effectiveness," Military Review, July-Aug 2004, p.23.

3. MAJ John M. Spiszer, "Leadership and Combat Motivation: The Critical Task," Military Review, May-June 1999, p. 69.

4. LTC Donald M. Bradshaw, "Combat Stress Casualties: A Commander's Influence," Military Review, July-Aug 1995, p.20.

5. LTCOL Belenky USA, LTCOL Noy IDF, MAJ Solomon IDF, "Battle Stress: The Israeli Experience," Military Review, July 1985: 28-37.

6. Anthony Kellet, Combat Motivation: The Behavior of Soldiers in Battle. Boston: Kluwer Nijhoff Publishing, 1982, p. 313.

7. CAPT Rodney Mitchell, "Enhancing Unit Cohesion," Military Review, May 1981: 30-43.

8. S. Noy, "Combat Psychiatry: The American and Israeli Experience," Contemporary Studies in Combat Psychiatry, edited by G. Belenky (New York: Greenwood Press, 1987), p.69-86.

9. Wong, Leonard, et. al. "Why They Fight: Combat Motivation in the Iraq War," (Carlisle, PA: Strategic Studies Institute, July 2003), pp. 22-23. (ISBN: 1-58487-133-4).

KEYWORDS: Infantry, Combat, Casualties

SB082-037 TITLE: Platform Independent Omni-Directional Antennas

TECHNOLOGY AREAS: Air Platform, Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop an omni-directional antenna that can operate efficiently from 6 – 18 GHz and facilitate high performance independent of mounting location.

DESCRIPTION: As missile systems become more available throughout the world, there is a need to further the development of missile launch detection and tracking technology. The widespread and growing use of inexpensive wireless systems for explosive devices, communication, and surveillance has also created a need to proliferate RF sensor systems. Advances in highly efficient, low-cost antenna systems would facilitate performance and cost improvements in these systems. These systems need to operate in any kind of environment, whether airborne, fixed terrestrial, or mobile. The antenna system performance must support independent operation of its host platform. The receive-only antenna needs to be wideband and truly omni in both amplitude and phase (i.e., no phase irregularities in azimuth and elevation) and be able to receive any of the myriad of communications signals, including military communications systems, cellular systems, WLAN, WiMAX, surveillance and targeting radars, and ultra wide band signals. One of the enabling components of this new concept in monitoring technology is the interface between the sensor receiver and free space; namely the antenna. An antenna for this surveillance platform must not only be small, but it must also be reconfigurable to ensure that maximum efficiency, dynamic mutual coupling tolerance, and coverage area is achievable at all times, for any frequency and in any environment. The development of this new form of wireless technology is extremely challenging and will require orders of magnitude advances in performance in several new RF/electromagnetic/antenna R&D areas. New smart materials that can adaptively control the direction of the radiation over a wide band of frequencies could help make the antenna effectively independent of its surroundings. Intelligent impedance matching circuitry between the antenna output and the wideband receiver can ensure maximum power is delivered to the receiver helping to improve the overall efficiency of the antenna platform and contribute to its independence of the mounting environment over a wide band of frequencies. New antenna size reduction techniques for the radiator and related circuitry can help ensure an unobtrusive solution can be developed.

PHASE I: Thoroughly investigate through simulation and experimentation whether the concepts discussed above can help to create an unobtrusive wideband reconfigurable antenna. Establish a trade-space between performance and size and other critical factors. In Phase I consideration to how these concepts can be integrated to give an efficient solution should also be undertaken.

PHASE II: Develop working prototypes of the new antenna concept including incorporating any smart material and appropriate control circuitry and algorithms for the adaptive aspects of the antenna. Undertake thorough testing of the performance of the prototypes in a laboratory environment including return loss characterization and radiation patterns across the wide band of operation and evaluate the performance of the antenna platform when mounted in several possible scenarios (such as mounted on a wall or on a person). In this phase of the program techniques to ensure efficient integration with the wideband receiver should also be considered as well as procedures to ensure a structurally robust solution can be achieved.

PHASE III: There are many applications that can benefit from this new technology; both military and commercial. Wideband, omni-directional platform independent antennas can be used in avionics, communication, radar/telemetry, electronic warfare, WiFi, cellular, and other commercial and DoD wireless applications. Importantly this new technology overcomes the issue of many radiators vying for limited real-estate on the one platform. Some specific military uses include wideband communication systems such as JTRS and future intelligent wireless communications that use either terrestrial or satellite links depending on the availability. Wideband electronic warfare receivers are another prime military insertion point for this technology. On the commercial side, future Software Defined Radio systems or cognitive radio require wideband antennas that have flexibility in their radiation performance to ensure maximum flexibility and capacity.

REFERENCES:
1. D. Sievenpiper, J. Schaffner, H. J. Song, R. Loo, G. Tangonan, "Two-dimensional beam steering reflector using an electrically tunable impedance surface," IEEE Trans. Antennas & Propagat., Vol. 51, pp. 2713 – 2722, October 2003.

2. A. Sanada, C. Caloz and T. Itoh, "Planar distributed structures with negative refractive properties," IEEE Trans. Microwave Theory & Tech., Vol. 52, pp. 1252 – 1263, April 2004.

3. C.-J. Lee, K. M. K. H. Leong and T. Itoh, "Design of resonant small antenna using composite right/left-handed transmission line," Proc. IEEE Inter. Symp. Antennas & Propagat., Washington, DC, July 2005, Volume 2B, pp. 218-221 (Paper s060p02a).

4. R. Abhari and G. V. Eleftheriades, "Metallo-dielectric electromagnetic bandgap structures for suppression and isolation of parallel-plate noise in high-speed circuits," IEEE Trans. Microwave Theory & Techniques., Vol. 51, pp. 1629 –1639, June 2003.

5. R. B. Waterhouse, S. D. Targonski and D. M. Kokotoff, "Design and performance of small printed antennas," IEEE Trans. Antennas & Propagat., Vol. 46, pp. 1629 – 1633, Nov. 1998.

6. J. Mingo, A. Valdovinos, A. Crespo, D. Navarro, and P. Garcia, "An RF electronically controlled impedance tuning network design and its application to an antenna input impedance automatic matching system," IEEE Trans. Microwave Theory & Techniques., Vol. 52, pp. 489 – 497, Feb. 2004.

7. H. Wheeler, "Fundamental limitations of small antennas," Proceedings of IRE, Vol. 35, pp. 1479 – 1484, Dec. 1947.

8. L. Chu, "Physical limitations of omni-directional antennas," Journal of Applied Physics, Vol. 19, pp. 1163 – 1175, Dec. 1948.

9. P. Burns, Software Defined Radio for 3G. Boston, MA: Artech House, Inc., 2002.

KEYWORDS: Antenna, Active Matching, Cognitive Radio, Small Antennas, Wideband, Omnidirectional, Phase Stable

SB082-038 TITLE: Electro-Optic Frequency-Agile Modulators

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Design, and develop a low optical loss, very-high performance, electro-optic frequency-agile modulator which can be used for the next generation advanced optical-domain signal processing of very high-frequency (microwave/millimeter-wave) signals. The frequency-agile modulator can frequency-shift an optical signals frequencies up to 60 GHz using one device. It should be dynamically programmable to adapt to the application.

DESCRIPTION: One of the next microwave photonic system applications is high-speed, high-resolution, electro-optic signal processing of microwave/mm-wave signals. Examples include the generation and control of high-purity microwave/millimeter wave signals, up and down frequency conversion for coherent heterodyne systems, sensors, sub-carrier multiplexing systems, frequency-shift-key (FSK) for advanced digital communication systems, etc. Conventional optical intensity and phase modulation approaches have matured and now the well-known and newly-discovered advantages of other advanced modulation formats must be explored. These formats include optical frequency-shifters, single-sideband (SSB), double-sideband (DSB), with/without carrier suppression modulation that can be used in a variety of optical signal processing functions for RF signals.

To be most effective for high-dynamic-range microwave systems, modulators for advanced formats must exhibit very-low insertion loss, very-high modulation efficiency (low-drive-voltage), and compatible with broadband (10-60+GHz), frequency-agile (dynamically frequency shifted) operation. In addition, frequency sideband signal purity, coherence, including unwanted sideband suppression (as in the case of carrier-suppression), must be extremely high. Although these types of modulators have been mentioned in the literature, advanced-format electro-optic modulators are not readily available with sufficient performance in terms of insertion loss, modulation efficient, bandwidth of operation, and signal purities. The objectives for this SBIR topic are to develop these types of modulators and explore their application to the next generation of microwave/photonic sensors, processing, and transmission systems. These systems are applicable to military signals capture and analysis as well as high spectral density modulation formats in commercial applications.

PHASE I: Feasibility study of designs for high performance frequency-agile sideband modulators applicable to microwave/millimeter-wave optical signal processing. Study should include exploring new system applications of such modulation format for high-dynamic-range RF fiber-optic transmission/sensing/signal processing and wideband “digital” communication systems.

PHASE II: Develop a very-low-loss, high-efficiency, optical sideband modulator capable of 10-60GHz operation with excellent suppression of unwanted sidebands. System insertion and characterization is encouraged to best demonstrate new application areas for such modulation format.

PHASE III: Dual use applications include dense wavelength division multiplexing and millimeterwave subcarrier multiplexing on the commercial telecom side. For the military, advanced modulation including single sideband modulation would benefit numerous RF systems that utilize up- and down-conversion and require easy access to a large frequency range for frequency shift keying, ultrawide spreadspectrum, or adaptive spectral utilization.

REFERENCES:
1. Izutsu, Shikama, and Sueta, “Integrated Optical SSB Modulator/Frequency Shifter”, IEEE Journal of Quantum Electronics, Vol. QE-17, No. 11, November 1981 (pp 2225-2227).

2. Takesue, Horiguchi, and Kobayashi, "Numerical Simulation of a Lightwave Synthesized Frequency Sweeper Incorporating an Optical SSB Modulator Composed of Four Optical Phase Modulators", Journal of Lightwave Technology, Vol. 20, No. 11, November 2002 (pp. 1908-1917).

3. Han, Jalali, Han, Seo, Fetterman, "Demonstration and analysis of Single Sideband Photonic Time-Stretch System,” IEICE Trans Electron. Vol. E86-C, No. 7, July 2003 (pp. 1276-1280).

4. Kawanishi, Oikawa, Yoshiara, Sakamoto, Shinada, and Izutsu, "Low Noise Photonic Millimeter-Wave Generation Using an Integrated Reciprocating Optical Modulator,” IEEE Photonics Technology Letters, Vol. 17, No. 3, March 2005 (pp. 669-671).

5. Nakatogawa, Maeda, Oyamada, "Optical single sideband modulator for distribution of digital broadcasting signals on millimetre-wave band based on self-heterodyne,” Electronics letters, Vol. 40, No. 21, Oct 14, 2004 (pp. 1369-1370).

KEYWORDS: Electro-Optic Modulators, Wideband, SSB, DSB, Optical Frequency-Shifter, Optical Signal Processing

SB082-039 TITLE: Lithium Niobate (LiNbO3) Device with Improved Efficiency and RF Filtering Applications

TECHNOLOGY AREAS: Air Platform, Materials/Processes, Sensors, Electronics, Space Platforms, Weapons

ACQUISITION PROGRAM: N/A

OBJECTIVE: To develop a Lithium Niobate (LiNbO3) device with improved electro-optical efficiency to enable concurrent antenna remoting and RF filtering by considering novel device designs.

DESCRIPTION: Fiber-optic links operating at microwave frequencies are crucial to next generation military radar communication systems, since they can enable antenna remoting with low link loss. Furthermore, fiber-optical technologies can potentially replace their electronic counterparts in accomplishing such critical functions as microwave signal processing in radar communication systems. The broad bandwidth and low transmission losses afforded by the optical fiber coupled with its immunity to electromagnetic interference make it the transmission medium of choice for such applications. However, to be rapidly adopted and deployed in military systems fiber-optical links should operate with low noise figure (NF), coupled with link gain and should allow for large dynamic range operation. Such system level requirements place very demanding performance and reliability specifications on the components that constitute the system, primarily the laser, the modulator, and the photodetector. The laser should be capable of very high-power (> 1W) operation with low relative intensity noise (RIN). The modulator should be able to withstand high optical input powers without sustaining optical damage and be capable of a low Vƒà (~ 1 V) and low optical insertion loss (~ 5 dB) operation. The phototector should be able to withstand several hundreds of mWs of optical power and operate in a linear regime with a high responsivity (~ 0.9 mA/mW).

Concurrently meeting all these requirements has proven elusive in state-of-the-art approaches. While significant progress has been made [1], state-of-the-art modulators still suffer from significant optical damage in the presence of large optical powers (~1W), and their optical insertion loss is also high (~ 10 dB). The main reason for the limited success of prior efforts is that there exists a number of trade-offs relating two or more modulator characteristics. Specifically, a lower Vƒàƒnƒn requires a longer electrode. This in turn leads to a longer device that results in a higher electrical and optical insertion loss. Since the maximum length of a LiNbO3chip is limited in practice, folded designs have been considered. Despite some progress achieved recently towards reducing optical loss in multiple-pass modulator structures, it still remains rather high and may defeat the very purpose of lowering Vpi. A high optical loss requires a high optical power at the input which may lead to optical damage.

Photodetectors on the other hand saturate at a few hundred mW of optical power and are not capable of linear operation. Hence, there is a need to develop a modulator technology that allows for high-sensitivity (low noise figure with link gain) operation while avoiding optical power damage, high optical insertion loss and photodetector saturation.

This SBIR topic focuses on the development of LiNbO3 modulators in order to enable high-sensitivity links (a link gain of 20 to 25 dB coupled with a noise figure in the 3-6 dB range) while avoiding optical power damage, high optical insertion loss and photodetector saturation. A further objective of the SBIR effort is the development of modulator designs that can also provide RF filtering. The proposed approach should be practical and may be implemented with a relatively low-cost, high-yield manufacture process.

PHASE I: Conduct a feasibility study on multi-gigahertz opto-electronic modulators that can simultaneously modulate multiple optic signals with a single RF input. As part of the study, design an electro-optic intensity modulator and analyze link performance for RF analog photonic applications. The bandwidth of operation of the device is expected to be in the 2 to 20 GHz range. Consider potential pay-offs in terms of combining the optical power in various ways to perform link or signal processing functions. In Phase I, specific design concepts with expected capabilities should be studied for fabrication consideration in Phase II.

PHASE II: Develop fabrication processes to enable the fabrication of the design proposed in Phase I. Fabricate and characterize the prototype device and demonstrate the target link performance. Thoroughly characterize the link performance (including measurement of modulator Vƒà, link gain and noise figure) and demonstrate that optical power damage, high optical insertion loss and photodetector saturation are not limitations.

PHASE III: Candidate applications for this technology span both the military and commercial arenas. In general terms, the analog photonic link components to be developed will be used in avionics, communication, radar/telemetry, electronic warfare, WiFi, instrumentation and other commercial and DoD transmission and signal processing applications. Some specific military uses include high bandwidth, multi-wavelength, fiber-optic signal transmission systems as well as optical time delay modules for broadband signal processing and phased-array antenna applications. Wideband electronic warfare receivers are another prime military insertion point for this technology including finite impulse response filters. On the commercial side, fiber radio for cellular access has become a significant commercial market. With the drive to offer broad-band wireless access, it is very likely that the market share of fiber-radio access systems will grow further. Now that the majority of fixed communication is by optical fiber, and per-channel data rates are rising through 40 Gb/s, the need for analog microwave photonic technology in this large market is assured.

REFERENCES:
1. C.H. Cox III, "Analog Optical Links: Theory and Practice," Cambridge University Press (2004).

2. José Capmany, Beatriz Ortega, and Daniel Pastor, "A Tutorial on Microwave Photonic Filters," Journal Of Lightwave Technology, VOL. 24, NO. 1, P. 201, January 2006.

KEYWORDS: RF Photonics; Microwave Photonics; Electro-Optic Modulator; Mach Zehnder Modulator; Waveguides; Lithium Niobate, Manufacturing

SB082-040   TITLE: Self-Seeded Programmable Parametric Fiber Comb Source

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: N/A

OBJECTIVE: Execute a feasibility study to develop an all-fiber, fast reconfigurable comb generator capable of arbitrary frequency grid synthesis, while providing true continuous wave (CW) response and sufficient power to support multiple feeds for general reference and clock provisioning.

DESCRIPTION: Multiple-frequency (comb) sources are general purpose instruments used in advanced radar [1], LIDAR [2], and communication [3], systems. Multiple-frequency sources are divided into broad classes of coherent and incoherent devices, with the former playing a critical role in phased and frequency-agile systems [4]. A jam-proof radar/lidar system exploits fast spectral hopping by using the coherent frequency comb for calibration or waveform synthesis purposes. A common example of incoherent comb is given by a set of independent sources combined by a conventional Wavelength Division Multiplexing (WDM) multiplexer: its spectrum forms a fixed CW wavelength comb. A WDM-multiplexed source is also an impractical construct since it implies unnecessary complexity (a 100-line comb requires 100 precisely stabilized lasers) and no flexibility (the comb spectral density is limited by the WDM multiplexer block). An alternative approach uses a single laser cavity oscillating at multiple frequencies simultaneously. However, the construction of such a device requires the combination of stabilized cavities and a spectrally equalized gain response; the tolerances placed on both are severe since each comb frequency competes for the available gain. Widely used class of coherent comb sources is based on mode-locked lasers: frequency characteristics of the comb are precisely defined by the cavity properties. Unfortunately, this class of sources is fundamentally limited because: a) the source stability (amplitude/temporal jitter) is defined by the stability of the cavity, b) CW operating regime is not possible. In addition, conventional sources are limited to equidistant frequency grid generation; an arbitrarily defined frequency plan (such as progressively offset frequency comb) is yet to be addressed.

A different class of comb sources [5], uses a recirculating frequency-shifting element to generate a set of stable, phase-locked frequencies. A single-sideband modulator (SSB) comb generator, used as a frequency-shifting element, translates the seed laser by a precise, RF-defined frequency during each pass within the fiber loop. The internal loop loss is offset by the gain element which, in contrast to Modelocked (ML) sources, does not enable lasing but loss-balancing only. The presence of this gain element is the critical design limitation since: 1) The bandwidth of the system (comb spectral width) depends on the available amplifier bandwidth. 2) The noise characteristic of the amplifier ultimately determines the carrier-to-noise ratio (CNR) of the generated comb. Both constraints can be addressed by introducing the parametric (phase-sensitive) gain element instead of conventional (phase-insensitive) amplifier:
1. The amplifier bandwidth can be substantially wider than the gain bandwidth of conventional amplifiers such as Erbium Doped Fiber Amplifier (EDFA), Raman or Semiconductor Optical Amplifier (SOAs), thus providing for

high-count harmonic generation.
2. The noise figure (NF) of the parametric gain block can, in principle, be considerably lower than that of a phase-insensitive amplifier by operating the system in phase-locked regime. An optimal system (NF~1) would allow for comb generation with CNR approaching that of original seed tone.

More importantly, the parametric gain block can be used in a self-seeded frequency role: an original seed frequency, split by SSB modulator in two tones can be subsequently mixed within the parametric gain block to generate additional frequencies via four-photon mixing. If the practical self-seeding in parametric block can be validated, the next generation of universal comb and clock references would be superior to any existing device in performance, dissipation and packaging footprint.

PHASE I: Execute a study for a parametric recirculating loop generation of an arbitrary frequency comb. Rigorous design of the reconfigurable comb architecture will be completed and a set of engineering rules will be derived. A formal plan for Phase II will be stated and proposed.

PHASE II: The design from Phase I will be finalized and subcomponent tested. The validation of reconfiguration and noise accumulation will be quantified using the testbed assembly. The prototype unit will be derived from the testbed and manufactured under frequency agile and frequency stable operating conditions.

PHASE III: The reconfigurable comb is a critical element in commercial (optical coherence tomography, diagnostics, metrology) and military (coherent radar, LIDAR, secure communications) applications. Two separate applications (commercial/military) will be targeted by specifically designing the fieldable units.

REFERENCES:
1. Seeds, A. J., Williams, K. J., Microwave Photonics, J. Lightwave Technol. Vol. 24, No 12, 4628-4641, 2006.

2. Weitkamp, C. (Ed.), LIDAR, Springer-Verlag, New York 2005.

3. Sakamoto, T., Kawanishi, T., Izutsu, M., 50-nm Wavelength-Tunable Self-Oscillating Electro-Optic Frequency Comb Generator, Optical Fiber Communication Conference, 2006 and the 2006 National Fiber Optic Engineers Conference, Anaheim, 2006.

4. Velsko, S. P., Ruggiero, A., Herrnan, M., Frequency Agile OPO-based Transmitters for Multiwavelength DIAL, Proc. SPIE Vol. 2833, p. 144-152, Application of Lidar to Current Atmospheric Topics, 1996.

5. Yamanaka A., Yamamoto M., Tanaka Y., Kurokawa T., Kawanishi T., Izutsu M., A Multi-Wavelength Light source using an optical single-band modulator and an arrayed waveguide grating, Lasers and Electro-Optics, 2003. CLEO/Pacific Rim 2003, Vol. 2, p.714, 2003.

KEYWORDS: Frequency Combs, Agile Frequency Sources, Coherent Radar, Coherent LIDAR

SB082-041 TITLE: Extended Duration Arbitrary Waveform Generation over Large Bandwidths

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Design, develop and fabricate hardware that provides high bandwidth (>100 GHz to 1 THz) modulated laser light with an arbitrary modulation format over very long time apertures (>10 microseconds). This aperture time represents a significant improvement over the current state of the art of photonic arbitrary waveform generators. Control over both amplitude and phase of the optical fields is required.

DESCRIPTION: Photonic approaches to generating arbitrary waveform via pulse shaping stemming from manipulating mode-locked laser combs have been well accepted. These techniques suffer from limited duration pulses among other factors. Several orders of magnitude of improvement in duration of waveforms is required for applications that include ultra-wideband secure communications with phase and amplitude modulation, laser radar, and millimeter wave fiber radio with non-repetitive spread spectrum optical data trains. Anticipated techniques would compete directly with these pulse shaping techniques to produce user defined long time-aperture shaped emissions over wide bandwidths, and providing time bandwidth products >10,000.

PHASE I: Prepare a feasibility study and concept design of hardware to produce optical arbitrary waveforms as specified.

PHASE II: A concept prototype will be built and tested according to the results of Phase I. Under the workplan, algorithm development will be expected to support the user-defined aspect of arbitrary waveforms. A study of hardware's readiness for military use and functionality should be addressed, including potential system applications.

PHASE III: Candidate applications for this technology span both the military and commercial arenas. The optical arbitrary waveform generation to be developed will be used in ultra-wideband secure communications with phase and amplitude modulation, laser radar/telemetry and millimeter wave fiber communication links for fiber radio and fiber CATV. Some specific military uses include high bandwidth, high resolution laser radar. On the commercial side, this technology will be a component of fiber radio for cellular access.

REFERENCES:
1. Mullen, L., et al., "Application of radar technology to aerial lidar systems for enhancement of shallow underwater target detection", IEEE Transactions on Microwave Theory and Techniques, Vol. 43, No. 9/2, pp. 2370-2377, Sept. 1995.

2. Ogawa H., et al., "Millimeter-wave Fiber Optics Systems for Personal Radio Communication", IEEE Transactions on Microwave Theory and Techniques, Vol.40, No. 12, pp. 2285-2293, Dec. 1992.

3. Gnauck A.H., et al., "Optical Phase-Shift-Keyed Transmission", J. Lightwave Technol., Vol. 23, No. 1, pp. 115-130.

KEYWORDS: Modulated Laser Light, Photonics, Waveform Generation

SB082-042 TITLE: <u>High Power Parametric Fiber Blue-Green Source</u>

TECHNOLOGY AREAS: Ground/Sea Vehicles, Biomedical, Weapons

ACQUISITION PROGRAM: N/A

OBJECTIVE: Execute a feasibility study to develop compact, efficient multiple-Watt blue-green sources with addressable operating wavelengths capable of near-diffraction limit and arbitrary modulation.

DESCRIPTION: In contrast to near-infrared, the visible band applications are yet to be addressed by tunable, high-power sources. While critical applications [1] in blue-green band await high-power solution, key technical blocks have matured and provide a clear path to construction of a new class of parametric sources. Firstly, high-powered diode lasers have become commercially available due to their use as pump sources for Diode Pumped Solid State (DPSS) Yttrium Aluminium Garnet (YAG), DPSS Yttrium Vanadate (YVO4), rare-earth doped fiber lasers (Yb, Er, Bi and Th) as well as Raman amplifiers for long-haul telecommunication systems. Competition and other market pressures have continually improved the performance of diode laser pumps such that electrical to optical conversion efficiencies greater than 50% are now routine as are lifetimes of several 10's of thousands of hours even at powers approaching 100 W per bar. The diversity of applications has also rendered these devices inexpensive and readily available.

Secondly, the advent of large mode-area (LMA) fibers now allow for kW class lasers emitting into a single spatial mode. These devices achieve their single mode nature by the use of large mode-area, dual-core fibers where the inner core is in fact multimode at the emission wavelength but coiled to suppress lasing in the higher order modes and so still achieve excellent beam quality.

Finally, the use of nonlinear effects (SBS) to “cleanup” the spatial characteristics of diode pump sources [2, 3, 4] motivated the demonstration of a single-mode Raman fiber laser using a multimode fiber.[5] The work by Baek and Roh convincingly showed that a multimode pump beam in a multimode fiber could be used to produce a single-mode output beam as a result of the physics of the nonlinear conversion process rather than by fiber-coil-induced mode selection. In related but independent work [6], Watts level emission at the sodium D-line for a guide-star application was demonstrated by frequency-doubling the Raman-shifted output from a fiber laser. It is plausible that the recent developments can be unified to produce first practical all-solid-state Watt class source in the blue-green spectral region capable of addressing arbitrary wavelength. A multimode fiber Raman laser development will spatially clean up and simultaneously frequency convert the low-brightness emission of high-powered diode pump lasers into high-brightness light appropriate for efficient nonlinear frequency conversion, via parametric processes, to produce blue-green wavelengths at high efficiency and high power compared to existing technologies.

PHASE I: Conduct a study to determine the feasibility of developing a multimode-fiber, multi-Watt, and Blue-Green Raman laser. Develop a preliminary design and expected performance to reveal quantitative advantages of the approach. Investigate the optimal fiber core diameter and the grating and pump laser parameters to understand requirements and to ascertain the likelihood of success of fabrication in a possible Phase II.

PHASE II: The design from Phase I will be finalized and subcomponent tested. Revise and improve model to incorporate thresholds for spectral broadening due to four-wave-mixing (FWM). Manufacture multiple units addressing specified sections of blue-green band and validate its operation at modulated and quasi-CW regime. Develop initial commercialization model.

PHASE III: Applications for the technology are both in defense (military) and commercial domains. The means for portable power projection in visible band will be used in submarine imaging, sensing and communications. High rate data transfer between submersible and undocked station (sensor node) is identified as critical application in both defense (submarine warfare) and commercial areas (undersea oil exploration). Of equal importance, the technology will allow for field scanning displays that are of immediate interest to military applications requiring high-grade visualization in harsh environments and to commercial projection display industry. Finally, the development of high power technology that can be tuned to hemoglobin spectral peak is expected to revolutionize surgery, particularly in field conditions such as battlefield areas.

REFERENCES:

1. W. P. Risk, T. R. Gosnell and A. V. Nurmikko, Compact Blue-Green Lasers, Cambridge Press, 2003.

2. B. C. Rodgers, T. H. Russell, W. B. Roh, Laser beam combining and cleanup by stimulated Brillouin scattering in a multimode optical fiber, Opt. Lett 24(16) p.1124-1126, 1999.

3. T. H. Russell, W. B. Roh, J. R. Marciante, Incoherent beam combining using stimulated Brillouin scattering in multimode fibers, Optics Express 8(2) pp246-254, 2001.

4. J. T. Murray, W. L. Austin, and R. C. Powell Intracavity Raman conversion and Raman beam cleanup, Opt. Mat. 11, pp. 353-371, 1999.

5. S. H. Baek, W. B. Roh, Single-mode Raman fiber laser based on a multimode fiber, Opt. Lett. 29(2) p153-156, 2004.

6. D. Georgiev, V. P. Gapontsev, A. G. Dronov, M. Y. Vyatkin, A. B. Rulkov, S. V. Popov, J. R. Taylor, Watts-level frequency doubling of a narrow line linearly polarized Raman fiber laser to 589-nm, Optics Express 13(18) p6772-6776, 2005.

KEYWORDS: Visible Sources, Submarine Sensors, Submarine Imaging, Battlefield Surgery

SB082-043 TITLE: Template-Based Lithography for Advanced Low-Volume Electronics

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop regular template-based lithography for cost effective, high resolution nanofabrication of low volume electronics.

DESCRIPTION: Current micro-fabrication technologies, especially for microelectronics are dominated by techniques optimized for very high volumes. DOD needs, for custom electronics, are typically for much lower volumes. Current commercial microelectronic manufacturing methods are not cost-effective in this regime. One of the potential solutions is to utilize template-based lithography to define the novel designs using highly regular patterns. Useful Complementary Metal Oxide Semiconductor (CMOS) patterns might be formed by a combination of regular template and trim/stitch lithographies. For this SBIR topic, we focus on the development of novel regular template-based lithographic approaches to address the requirements of sub-32nm CMOS technology nodes. In addition, the proposed approaches should be cost effective so that the throughput goal should be better than ten eight-inch wafers per hour. Possible methods may include optical interference or nano-imprint lithographies combined with the appropriate trim/stitch patterning steps.

PHASE I: Demonstrate feasibility of proposed regular template-based lithography. Determine, using simulation and/or basic experiments, what the expected throughput (wafers per hour or area per unit time) and resolution of the proposed method is. Propose realistic fabrication scenarios for typical micro/nano – electronic, photonic or Micro Electrical Mechanical (MEMs) components.

PHASE II: Develop a prototype system demonstrating throughput/resolution performance estimated in Phase I. Such a system should be capable of patterning large areas (e.g., 8" wafer) in reasonable times (better than 10 wafer per hour). Fine tune realistic fabrication scenarios for typical micro/nano – electronic, photonic or MEMs components.

PHASE III: Military and civilian applications include rapid prototyping or Application Specific Integrated Circuits (ASICs.)

REFERENCES:

1. J. P. Spallas, A. M. Hawryluk, and D. R. Kania, "Field emitter array mask patterning using laser interference lithography," Journal of Vacuum Science & Technology B, 13, 1973 (1995).

2. H. H. Solak, C. David, J. Gobrecht, V. Golovkina, F. Cerrina, S. O. Kim and P. F. Nealey, "Sub-50 nm period patterns with EUV interference lithography," Microelectronic Engineering, 67, 56 (2003).

3. Takashi Ito, Shinji Okazaki, "Pushing the limits of lithography," Nature, 406, 1027 (2000).

4. A.A. Tseng, Chen Kuan, C.D. Chen, K.J Ma, "Electron beam lithography in nanoscale fabrication: recent development," IEEE Transactions on Electronics Packaging Manufacturing, 26, 141 (2003).

5. V. Shevchenko et. al., "Structural diversity in binary nanoparticles superlattices," Nature, 439, 55 (2006).

6. S.V. Sreenivasan et. al., "Enhanced Nanoimprint process for advanced lithography applications," Semiconductor Fabtech, 25th edition, pp.107-113 (2005).

7. X. Cheng and L. J. Guo, "A combined nanoprint and photolithography patterning technique," Microelectronic Eng. vol. 71, pp. 277-282 (2004).

8. M. Li et. al., "Direct three-dimensional patterning using nanoimprint lithography," Appl. Phys. Lett. vol. 78, pp. 3322-3324 (2001).

KEYWORDS: Low-Volume Manufacturing, Micro/Nano – Fabrication, Maskless Lithography, Hybrid Lithography/Patterning, Asics, Rapid Prototyping

SB082-044 TITLE: Highly Integrated Silicon (Si)-Based RF electronics

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop methods to achieve unprecedented levels of integration for Si-based RF electronics in support of emerging DoD-critical applications such as wafer-scale phase array radars, highly-integrated electronic warfare systems, or compact sensing systems.

DESCRIPTION: Driven by Moore's law, the downscaling of silicon-based technologies, such as Silicon Complementary Metal Oxide Semiconductor (CMOS) or Silicon-Germanium Bipolar-CMOS (SiGe BiCMOS) technology, have pushed silicon transistor performance close to III-V materials with cutoff frequencies exceeding 350GHz. As a result, useful RF front-end circuits now can be fabricated in silicon-based technologies. Many prototype high performance Si-based RF/mixed signal circuits have been demonstrated for wireless communications, automotive, radar-on-a-chip, or electronic warfare applications. These preliminary demonstrations clearly illustrate the potential impact on reducing the size, weight and power (SWAP) of very complex RF front-ends, as well as providing many new cost-effective mission capabilities/options for emerging DoD-critical applications.

In comparison to state-of-the art III-V technologies, the truly unique properties of silicon-based RF/analog technology include unprecedented levels of cost-effective integration for highly complex RF, microwave, mm-wave and analog/digital/mixed-signal modules. The RF/analog performance metrics of silicon (speed, breakdown voltage and power) are not necessarily competitive with alternative material device structures, but the high level of integration of silicon-based RF/analog technology offers potential for further exciting avenues for progress. This SBIR topic will focus on developing unprecedented levels of integration for Si-based RF electronics that can provide revolutionary capabilities or high performance that can not be achieved by current III-V technologies. Some example RF/mixed signal circuits or components may include digitally-assisted low-power high-resolution wide-band analog-to-digital converter, CMOS compatible on-chip antennas, highly-integrated wafer-scale phase array, or other revolutionary circuits. Possible fabrication technologies could include RF CMOS or SiGe BiCMOS technologies perhaps combined with 3D integration techniques or other advanced assembly/packaging approaches.

PHASE I: Analyze the feasibility of the proposed integration scheme and RF/mixed signal circuits that will result in revolutionary capabilities or superior performance which can not be achieved by current III-V technologies. Determine, using simulation and/or basic experiments, the expected RF performance, the integration level (RF and digital transistor counts), and required integration technologies (3D integration, etc.) of the proposed circuits. Propose realistic fabrication technologies or necessary technology developments to realize the target RF/mixed signal circuits for the next phases.

PHASE II: Develop prototype circuits demonstrating proposed highly integrated RF/mixed signal performance estimated in Phase I. The demonstration circuits should be fabricated by proposed Si-based technologies and integration methods.

PHASE III: The highly complex and integrated Si-based RF/mixed signal electronics should be broad enough for both DoD and commercial applications. Commercial applications may include wireless voice/data communications, industrial control and automation, automotive radar, etc.

REFERENCES:
1. B.A. Floyd, S.K. Reynolds, U.R. Pfeiffer, T. Zwick, T. Beukema, B. Gaucher, “SiGe bipolar transceiver circuits operating at 60 GHz,” IEEE Journal of Solid-State Circuits, 40, 156 (2005).

2. M. Fritze, C.L. Chen, S. Calawa, D. Yost, B. Wheeler, P. Wyatt, C.L. Keast, J. Snyder, J. Larson, “High-speed

Schottky-barrier pMOSFET with fT=280 GHz," IEEE Electron Device Letters, 25, 220 (2004).

3. Y.-L. Chao, J. C. S. Woo, "Source/Drain Engineering for Parasitic Resistance Reduction for Germanium p-MOSFETs," IEEE Transactions on Electron Devices, 54, 2750 (2007).

4. Mau-Chung Frank Chang, "Impact of CMOS Scaling on RF/Mixed-Signal Circuit Designs," 2006 International Solid-State and Integrated Circuit Technology Conference, page 1514 (2006).

5. S. Emami, C.H. Doan, A.M. Niknejad, R.W. Brodersen, "A Highly Integrated 60GHz CMOS Front-End Receiver," 2007 IEEE International Solid-State Circuits Conference Digest of Technical Papers, page 190 (2007).

KEYWORDS: RF CMOS, SiGe HBT, Radar-on-a-Chip, 3D Integration, On-Chip Antenna, Fabrication

SB082-045 TITLE: Innovative Approaches to Low Power, Sub-Threshold Electronic Circuits

TECHNOLOGY AREAS: Sensors, Electronics, Space Platforms

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop and demonstrate innovative logic, memory, and design technologies which maximize processing energy efficiency and power savings, while still maintaining adequate performance, using sub-threshold digital circuit operation for ultra-low power military system processing.

DESCRIPTION: Ultra-low power processing for DoD electronic systems, particularly those that must operate for prolonged periods on batteries, can have a major impact in determining the size, weight and endurance of military electronics and significantly impact mission capabilities. Subthreshold voltage operation, bias regimes well below where circuits typically operate, of Silicon Complementary Metal Oxide Semiconductor (Si CMOS) based devices, can provide the needed ultra-low power processing and enable the implementation of many long endurance operational systems such as remote sensor networks as well as small unit communications and other wireless applications. Despite successful subthreshold circuit research activity, very little technology exists to implement the technology on a fielded DoD system. Subthreshold circuit approaches which would enable digital processing at very low voltages include sub-threshold logic and memory cell designs that can be used with standard design flows and commercially available CMOS processes, programmable processors that operate efficiently at sub-threshold voltage, and circuit design tools that can mitigate device variability or correct errors on the fly often caused by sub-threshold operation. Since maintaining adequate performance is critical to the objective of this topic, these methods might be combined with micro-architectural advances for maintaining performance such as ultra-dynamic voltage scaling, 3D circuit topologies providing the increased area to leverage application-specific parallism, and body bias based threshold tuning.

PHASE I: Perform a feasibility study of a sub-threshold circuit technology, showing power saving benefits relative to nominal voltage operation. Analyze performance impact and feasibility of implementing the technology in a standard circuit design flow using available foundry offerings. Describe prototype chip that would demonstrate power saving benefits with maximum performance capabilities.

PHASE II: Design and fabricate an ultra-low power, sub-threshold integrated circuit prototype chip as described during Phase I. Provide measurements evaluating power savings and performance of the circuit. Identify limitations and requirements for embedding in DoD power constrained system.

PHASE III: DoD relevance includes radio/comms, (radio Frequency) RF-microwave, unattended-sensors. Civilian applications include mobile communications and computing.

REFERENCES:
1. Wang, Calhoun and Chandrakasan, "Sub-Threshold Design for Ultra-Low Power Systems," Spring 2006.

2. Bo Zhai, Scott Hanson, David Blaauw, Dennis Sylvester. "Analysis and Mitigation of Variability in Subthreshold

Design". ACM/IEEE International Symposium on Low Power Electronics and Design, August, 2005.

3. A.Raychowdhury, B. Paul, S. Bhunia, and K. Roy, Computing with Subthreshold Leakage: Device/Circuit/Architecture Co-Design for Ultralow-Power Subthreshold Operation, IEEE Transactions on VLSI Systems, November 2005, pp. 1213-1224 (no. 105).

KEYWORDS: Ultra-Low Power, Electronics, Circuits, Devices Variability, Subthreshold Voltage

SB082-046 TITLE: Compact Multi-Spectral Micro-Optic Imager

TECHNOLOGY AREAS: Sensors

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop the optical train for a multispectral imager based on microoptical elements that is ultracompact compared to similar current optical systems.

DESCRIPTION: This topic seeks to develop compact optical trains for multispectral imagers. Current multispectral imagers are bulky and cannot be hand held. This is due to their large optical systems which are needed to simultaneously collect both the spatial and spectral data. These optics form >90% of the total system size. In addition, as the wavelength range and spectral resolution of the imager increases so does the imager volume with typical volumes being many tens to hundreds of cubic centimeters. Recently fabrication techniques have been developed to produce high performance microoptical elements, such as lenses and prisms. These microoptical elements form the core of the optical train for a multispectral imager and their incorporation into a system would vastly reduce the overall system size. In addition, advanced data compression techniques will further improve the system by allowing the data to be collected more efficiently.

PHASE I: Conduct a feasibility study on the microoptical system and data collection algorithms required for a compact multispectral imager.

PHASE II: Demonstrate a brassboard compact multispectral imager for the wavelength range 400-1000 nm with 256X256 pixel spatial resolution. The optical components will occupy a volume <1 cubic centimeter.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can transform both military and civilian imaging and identification systems into handheld devices.

References:
1. C. Gimkiewicz, D. Hagedorn, J. Jahns, E.-B. Kley, F. Thoma, “Fabrication of Microprisms for Planar Optical Interconnections by Use of Analog Gray-Scale Lithography with High-Energy-Beam-Sensitive Glass,” Applied Optics, 38, (1999), p. 2986.

2. A. Akiba, K. Iga, “Image multiplexer using a planar microlens array,” Applied Optics, 29, (1990), p. 4092.

3. M. Kurihara, M. Abe, K. Suzuki, K. Yoshida, T. Shimomura, M. Hoga, H. Mohri, N. Hayashi, “3D structural templates for UV-NIL fabricated with gray-scale lithography,” Microelectronics Engineering, 84, (2007), 999.

4. N.P. Eisenberg, M. Manevich, A. Arsh, M. Klebanov, V. Lyubin, “New micro-optical devices for the IR based on three-component amorphous chalcogenide photoresists,” J. Non-Cryst. Solids, 352, (2006), p. 1632.

KEYWORDS: MicroOptics, MultiSpectral Imaging, Algorithms

SB082-047 TITLE: Ultra-Low Noise, Wide Bandwidth Constant Current Sources for Driving Laser Diode Arrays

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: N/A

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 low-noise driver technologies and methodologies that will enable high efficiency laser diode bars to operate reliably at optical powers exceeding 250W/bar-cm.

DESCRIPTION: High power solid-state lasers and laser diodes that operate reliably for long periods of time are becoming increasingly important to the US military. These applications include advanced LIDAR for atmospheric and terrestrial mapping and weather prediction, and emerging classes of high power laser weapons for protecting high value assets, and for defensive countermeasures. Since high power and good thermal management in military systems are key issues to be addressed, it is essential to utilize the most advanced and highest efficiency laser diode arrays. One drawback with present high power laser diode bars is they can be unreliable at power levels exceeding 100W per bar-cm. Diode reliability problems that result from electro-optical instabilities can be mitigated in part with low-noise, wide bandwidth constant current sources that adjust the drive power to avoid these instabilities. Consequently, it is important to develop innovative driver technologies and methodologies that will enable high efficiency laser diodes to operate reliably at optical power in excess of 250W/bar-cm.

PHASE I: Feasibility study to design an ultra-low noise constant current source that is capable of controlling laser diode drive current on the sub-microsecond time scale.

PHASE II: Fabricate a compact, ultra-low noise constant current source capable of driving high power diode arrays. Integrate the current source with laser diode arrays, and demonstrate improved laser diode performance and lifetime of at least factors-of-5 at power levels greater than 250W per bar-cm.

PHASE III: High power laser diodes will continue to have numerous applications in both military and commercial systems, ranging from metal-working and machining, to optical communications and sensors, and laser weapons.

REFERENCES:

1. Updated Laser Diode Bar Lifetest Failure Data Analysis, NASA-Goddard Space Flight Center Code 302, W. Thomas, Systems Safety and Reliability Office Technical Memorandum, 2004.

2. Reliability and Degradation of Semiconductor Lasers and LEDs, I.M. Fukuda, Artech House, Boston, 1991.

3. Generic Reliability Assurance Requirements for Optoelectronic Devices Used in Telecommunications Equipment, GRE-468-Core, Bellcore, Dec. 1998.

KEYWORDS: High Power Laser Bar, Laser Reliability, Current Source

SB082-048 TITLE: Beam Combining for High Power Quantum Cascade Laser Arrays

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: Demonstrate high power quantum cascade laser arrays while maintaining good beam quality.

DESCRIPTION: One of the primary benefits of semiconductor lasers is mass producibility and monolithic integration. Arrays of near infrared (808 or 980 nm) laser diodes are capable of extremely high power (60-100 W). The array is processed as one unit and handled/packaged in a similar manner to individual laser diodes. As the quantum cascade laser is also based on wafer-scale technology, the same array capability exists but has not been fully explored. While power output can generally be increased by increasing the number of emitters, there are two primary obstacles to maintaining efficient power delivery. The first is excess heat generation. Even the best quantum cascade lasers are only ~10% power efficient near room temperature. Packaging many lasers together in one monolithic array scales the heat generation along with the power, and thermal crosstalk will, in general, decrease the overall array performance.

The second major problem with laser arrays is beam quality. Given individual emitters with divergent output beams the total array is likely to have divergence that is significantly above the diffraction limit for a large emitting aperture. Thus, when using multiple cavities for high power output, a mechanism for combining individual cavity outputs into a single, high quality beam is required. Several techniques exist for coherent beam combining, including phased arrays and spectral beam combining, but these have not been yet applied to mid-wave or long-wave infrared sources. Mid-wave- (3<lambda<5 micron) and long-wave-infrared (8<lambda<12 micron) semiconductor lasers arrays that emit multi-watt average powers with beam qualities close to the diffraction limit would be highly desirable for compact, remote electro-optic systems. DoD applications include remote chemical sensing, infrared countermeasures and LADAR.

This topic seeks solutions to the technical problem of power scaling of quantum cascade lasers, without degrading their beam quality. Further, the solution should be applicable for any wavelength throughout the mid-wave- and long-wave-infrared atmospheric transmission windows.

PHASE I: Feasibility study to demonstrate a baseline electrically pumped quantum cascade laser that emits at least 200 mW of average power at a TE-cooler temperature in the 3-5 micron or 8-12 micron wavelength range. Wall-plug efficiency should be at least 4%. Develop a comprehensive plan, supported by modeling, for combining the output power of multiple emitters to >1 W while maintaining a beam divergence < 2 times the diffraction limit.

PHASE II: Demonstrate experimental phase combining of multiple emitters to a total power level >5 W average power levels while maintaining a beam divergence < 2 times the diffraction limit.

PHASE III: In addition to the DoD need for advanced chemical sensors, IR countermeasures and LADAR, the commercial sector also has uses for this technology in detection of toxic industrial gases and atmospheric pollution monitoring.

REFERENCES:
1. “Evaluation of thermal crosstalk in quantum cascade laser arrays,” A. Soibel, K. Mansour, D.L. Sivco, A.Y. Cho, IEEE. Phot. Technol. Lett. 19(5-8), pp. 375-377 (2007).

2. “Near-diffraction-limited diode laser arrays by wavelength beam combining,” B. Chann, R.K. Huang, L.J. Missagia, C.T. Harris, Z.L. Liau, A.K. Goyal, J.P. Donnelly, T.Y. Fan, A. Sanchez-Rubio, G.W. Turner, Opt. Lett. 30(16), pp. 2104-2106 (2005).

3. “Phase-locked ridge waveguide InGaAs-GaAs-AlGaAs strained-layer quantum well heterostructure laser arrays,” K.J. Beernink, L.M. Miller, T.M. Cockerill, J.J. Coleman, Appl. Phys. Lett. 59(25) pp. 3222-3224 (1991).

4. “CW phase-locked array Ga0.25In0.75As0.5P0.5-InP high-power semiconductor-laser grown by low-pressure metalorganic chemical vapor-deposition,” M. Razeghi, R. Blondeau, M. Krakowski, B. Decremoux, J.P. Duchemin, F. Lozes, M. Martinot, M.A. Bensoussan, Appl. Phys. Lett. 50(5) pp. 230-232 (1987).

KEYWORDS: Laser; Uncooled, Manufacturing, Quantum Cascade Laser

SB082-049 TITLE: Electrically-Pumped III-Nitride Intersubband Lasers

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: Demonstrate intersubband semiconductor lasers near a wavelength of 1.55 microns for high-speed applications.

DESCRIPTION: Semiconductor lasers are compact, robust and capable of high speed data transfer. Direct modulation of over 10 Gbit/s has been demonstrated. Unfortunately, due to long carrier lifetimes in traditional interband diode lasers, higher speed modulation typically requires external modulation. For high bandwidth communication, wavelength division multiplexing is typically used, which requires multiple laser sources and detectors to properly transmit large volumes of information. For 1 Tbit/s bandwidth, this requires 100 lasers. Thus, the benefits of having a compact and robust light source are negated by the system scale.

Intersubband lasers and detectors interact with light through electron transitions within specially designed quantum wells. The electron lifetime is controlled by electron-photon interactions, and is thus much shorter than what one would find in a traditional diode laser. For heavy electron mass systems, the carrier lifetime is extremely short, on the order of 150-400 fs for heavy effective mass systems such as the III-Nitrides. Properly utilized in a laser source this could potentially lead to Tbit/s data transmission from a single source.

While other intersubband lasers have been developed at longer wavelengths (3-190 ƒÝm), the short wavelength infrared is quite difficult to access as it requires very deep quantum wells. Traditional material systems such as InP or GaAs cannot achieve such deep quantum wells. On the other hand, the GaN/AlN quantum well system can achieve band offsets on the order of 2.1 eV, which is more than enough to realize 1.55 micron wavelength sensitivity.

Unfortunately, there are two primary challenges in realizing an electrically pumped III-Nitride intersubband laser. First, the short electron lifetimes make the spontaneous photon emission very inefficient. This makes it extremely difficult to generate photon gain, which makes the threshold current density intrinsically very high. The second problem is related to material growth and crystalline quality. For efficient tunneling transport, required in this type of structure, very thin (1-3 nm) Al(Ga,In)N layers are required, and interface roughness has a very large effect on the gain profile. At the same time, the choice of substrate is limited, which can lead to further, dislocation-based, degradation of the material quality.

In the literature, there has been research to show that intersubband absorption can occur in III-Nitride heterostructures at the required telecom wavelength (1.55 ƒÝm). Single quantum wells have demonstrated intersubband emission in the 2-2.5 ƒÝm wavelength range, and coupled quantum wells have shown clear absorbance signatures at even shorter wavelengths. As of yet, no electrically-pumped device has been demonstrated, but several designs have been postulated.

PHASE I: Investigate the design and limiting theoretical and experimental factors involved in producing intersubband emission from III-Nitride quantum wells and coupled quantum wells.

PHASE II: Demonstrate material characterization, including infrared absorption and/or emission, for a III-Nitride intersubband heterostructure sensitive to wavelengths near 1.55 ƒÝm. Demonstrate electrically pumped III-Nitride intersubband laser operating near room temperature at a wavelength of 1.55 ƒÝm.

PHASE III: Both the military and the commercial sector has extreme interest in a Tbit/s, direct modulation laser source. The same technology developed in this project is directly applicable to commercial data communication as well.

REFERENCES:
1. "Nitride intersubband devices: prospects and recent developments,¨ F.H. Julien, M. Tchernycheva, L. Nevou, L. Doyonnette, R. Colombelli, E. Warde, F. Guillot, E. Monroy, Phys. Stat. Sol. (a) 204, pp. 1987-1995 (2007).

2. “Designing strain-balanced GaN/AlGaN quantum well structures: Application to intersubband devices at 1.3 and 1.55 ƒÝm wavelengths,¨ J. of Appl. Phys. 93(6) pp. 3194-3197 (2003).

3. “High-quality AlN/GaN-superlattice structures for the fabrication of narrow-band 1.4 um photovoltaic intersubband detectors, ¨ Appl. Phys. Lett. 88, art. 121112 (2006).

KEYWORDS: Quantum Cascade Laser; High Bandwidth Data Link; III-Nitride Heterostructure

SB082-050 TITLE: Coherently Synchronized Distributed Signal Generation

TECHNOLOGY AREAS: Ground/Sea Vehicles, Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop an integrated circuit (IC) based clock distribution architecture which can be used for the large scale, affordable sub-picosecond synchronization of distributed processors, radios, and data samplers operating at 10s of GHz clock frequencies. The developed ICs should allow for the highly accurate wired distribution of a low frequency reference over 100s to 1000s of nodes.

DESCRIPTION: An alternative to the previously explored possibilities might be found by slaving many local high-frequency oscillators to a distributed low-frequency clock. The advantages of this technique are that it would allow the clock to be distributed over large distances and the distribution network could be realized on standard printed circuit boards (PCBs). Such a clock distribution network could be used to synchronize many digital/mixed-signal components on multiple PCBs and even between separate instrumentation racks. Such a system could also be used to provide synchronization over the digital/mixed-signal portions of very large phased arrays and for this reason is very interesting for the purposes of digital beamforming.

PHASE I: Develop and simulate concepts for affordable distributed clock generation at frequencies greater than 20 GHz capable of providing sub-picosecond synchronization over distances up to one meter. The developed clock distribution network should have the potential to provide signals with better than -90 dBc/Hz phase noise at a 100 KHz offset and should be able to demonstrate correction of up to 50 picoseconds of skew.

PHASE II: The previously developed concept should be demonstrated in a prototype that allows node level integration of the synchronization function. This prototype should demonstrate the potential for incorporation of the synchronization technology into a large scale synchronized network of distributed components (at least 100 synchronized nodes) operating at clock frequencies greater than 20 GHz. Further, there should be a means for correcting skew so that the combined synchronization error budget of both skew and jitter is less than 1 picosecond.

PHASE III: Candidate applications for this technology span both the military and commercial arenas. In general terms, the large-scale distributed clock synchronization scheme can be used in military radar, communications and EW systems, commercial aviation radar systems, high-speed data networks, and distributed sensor networks. Since the proposed approach is potentially very low-cost, there is strong potential for commercial development.

REFERENCES:
1. R. Walden, Analog-to-Digital Converter Survey and Analysis, IEEE Journal on Selected Areas of Communications, Vol. 17, No 4, 1999: 539-550.

2. T. Brooks, et. al., A Review of Synchronization Methods in Wireless Sensor Networks, 1st International Conf on Sensing Technology, Nov 21-23, 2005 Palmerston North, NZ.

3. http://www.silabs.com/public/documents/marcom_doc/mcoll/Timing/en/DSP_Driven_Clocks.PDF

4. M. Iqbal, et. al., Stochastic Wire Length Sampling for Cycle Time Estimation. SLIP 2002: 91-96.

5. R. Li, et. al., Wireless Clock Distribution System Using an External Antenna, IEEE J. of Solid State Circuits, Vol. 42, No. 10, 2007: 2283-2292.

6. H. Chang, et. al., Phase Noise in Externally Injection-Locked Oscillator Arrays, IEEE Trans. On Microwave Theory and Techniques, Vol. 45 No. 11, 1997: 2035-2042.

7. L. Zhang, et. al., Injection-Locked Clocking: A New GHz Clock Distribution Scheme, IEEE Conf on Custom Integrated Circuits, Sept, 2006: 785-788.

KEYWORDS: Fan-Out, Clock Synchronization, Skew, Distributed Timing, Aperture Error, Phase Noise, Jitter, PCB

SB082-051 TITLE: Efficient Small Antennas

TECHNOLOGY AREAS: Air Platform, Ground/Sea Vehicles, Sensors, Electronics

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop new technologies for the realization of small, unobtrusive antennas.

DESCRIPTION: The development of new, innovative size reduction procedures are sought that can be applied to antenna technology, in particular that allow the antenna to operate efficiently in different environments with the ultimate goal of operating as close as possible to the Chu limit [2]. This is a very challenging requirement that calls for novel approaches and technical solutions. Utilization of the three-dimensional packaging of the wireless sensor may be one alternative, or the use of new loading materials (such as electromagnetic bandgap structures [7], or the equivalent) may provide a small radiating solution. These techniques could also be applied to the ground-plane to reduce its size and therefore the entire antenna. The use of an accurate three-dimensional full-wave electromagnetic simulation tool that can assist with the proposed investigations into new small antenna technologies is an important aspect of this topic.

Once the new radiator technology has been established, there is still the issue associated with reduced efficiency/bandwidth. Even for the modest bandwidth requirements for most communication systems, small antenna technology cannot reach these targets; typically the gain of the power amplifiers or Low Noise Amplifiers are increased to compensate for the reduction in efficiency leading to reduced battery life of the radio. Intelligent impedance matching circuitry (sometimes referred to as non-fosters circuits) between the antenna and the transceiver could ensure the delivery of maximum power between the radiator and the transceiver, helping to improve the overall efficiency of the antenna platform [8]. How these intelligent matching circuits and the small antennas can be efficiently integrated to each other and the rest of the transceiver to improve the overall system objective is also of interest.

PHASE I: Thoroughly investigate through simulation new procedures and concepts to enable dramatic size reductions for low profile antennas. In this investigation, trade-spaces between performance (bandwidth and gain) and size and other critical factors should be undertaken. Also, comparisons with other well-known procedures (such as fractal antennas, shorting pins) should be conducted. Investigations into the feasibility of applying non-foster matching circuits to these small antennas and how such circuits can be efficiently integrated with the antennas should be conducted.

PHASE II: Develop working prototypes of the new antenna concept including the incorporation of any new materials and circuits. Undertake thorough testing of the performance of the prototypes in a laboratory environment including return loss characterization and radiation patterns across the band of operation and evaluate the performance of the antenna platform when mounted in several possible scenarios (such as mounted on metal, composites, etc). In this phase of the program, techniques to ensure efficient integration with the transceiver should also be considered as well as procedures to ensure that a structurally robust solution can be achieved.

PHASE III: The new antenna size reduction techniques while maximizing efficiency could be employed in future distributed wireless sensor systems for a variety of military and commercial surveillance and security applications as well as hand-held and man-portable wireless communication systems.

REFERENCES:
1. H. Wheeler, “Fundamental limitations of small antennas,” Proceedings of IRE, Vol. 35 No. 12, pp. 1479 – 1484, Dec. 1947.

2. L. Chu, “Physical limitations of omni-directional antennas,” Journal of Applied Physics, Vol. 19, pp. 1163 – 1175, Dec. 1948.

3. R. B. Waterhouse, S. D. Targonski, and D. M. Kokotoff, “Design and performance of small printed antennas,” IEEE Trans. Antennas & Propagat., Vol. 46 No. 11, pp. 1629 – 1633, Nov. 1998.

4. C.R. Rowell and R.D. Murch, “A capacitively loaded PIFA for compact mobile telephone handsets,” IEEE Trans. Antennas & Propagat., Vol. 45 No. 5, pp. 837 – 842, May 1997.

5. E. Lee, P.S. Hall, and P. Gardner, “Dual band folded monopole/loop antenna for terrestrial communication system,” Electronics Letters., Vol. 36 No. 24, pp. 1990 – 1991, Nov. 2000.

6. J. P. Gianvittorio and Y. Rahmat-Samii, “Fractal antennas: a novel antenna miniaturization technique and applications,” IEEE Antennas & Propagation Magazine, Vol. 44, pp. 20 – 36, Feb. 2002.

7. F. J. Broas, D. F. Sievenpiper, and E. Yablonovitch, “A high impedance ground-plane applied to a cellphone handset geometry,” IEEE Trans. Microwave Theory & Tech., Vol. 49 No. 7, pp. 1262 – 1265, July 2001.

8. J. de Mingo et al, “An RF electronically controlled impedance tuning network design and its application to an antenna input impedance automatic matching system,” IEEE Trans. Microwave Theory & Tech., Vol. 52 No. 2, pp. 489 – 497, Feb. 2004.

KEYWORDS: Antenna, Small Antennas, Active Antennas, Non-Fosters Circuits

SB082-052 TITLE: Indium Gallium Nitride (InGaN) Solar Cell

TECHNOLOGY AREAS: Materials/Processes, Sensors

ACQUISITION PROGRAM: N/A

OBJECTIVE: The goal of this research and development is a photovoltaic cell with a low energy cut-off between 2.1 eV and 3.0 eV.

DESCRIPTION: The value of InGaN for both photovoltaic and lighting applications is well known. The bandgap of the InGaN family virtually spans the solar spectrum such that theoretically, a tandem or graded solar cell optimizing solar energy collection could be made from this material system alone. As the lattice constant varies with indium composition, high quality structures with varying bandgaps cannot be monolithically grown. The material system is also plagued by (i) phase separation when the In composition increases above 15% and (ii) difficulties in obtaining optimal densities of electrically active p-type dopants. These latter two hurdles can be surmounted. While monolithic growth of multi-junction solar cells is helpful, it is not essential. An InGaN photovoltaic device can be combined with low cost silicon and/or other cells in a multi-junction device providing the potential for exceeding 40% power conversion efficiency.

This topic seeks InGaN growth and photovoltaic cell fabrication in an industrial environment to support high efficiency multi-junction solar energy technologies. The target specifications for the device are a single junction cell, a bandgap between 2.4 and 2.8 eV and transparency to sub-bandgap light. Devices with a bandgap between 2.1 eV and 3.0 eV are acceptable. InGaN growth with an appropriate bandgap and suitable doping levels must be demonstrated in Phase I and form the basis for a functional photovoltaic prototype in Phase II.

PHASE I: The offerer will conduct a feasibility study demonstrating the materials growth and documenting the design for a prototype solar cell. The offerer will develop and document the path forward and performance testing plan that will lead to a working photovoltaic device in Phase II.

PHASE II: The offerer will construct, test and evaluate the performance of the photovoltaic device designed in Phase I, including documentation of the final design and performance. The offerer will further provide a cost model and draft a preliminary path to large-scale commercial manufacturability of the device.

PHASE III: As an InGaN solar cell will enable high efficiency solar energy conversion; it supports all military and commercial applications that can benefit from solar energy. Military examples of technology that can be integrated with solar energy conversion include flashlights, radios, global positioning systems, other handheld technologies, stand alone sensors and autonomous vehicles. The largest commercial impact will be on providing high efficiency solar power to the grid. Other commercial opportunities include electric/hybrid cars, off-grid housing, cell phones and laptops.

REFERENCES:
1. Barnett, A. B., et. al., Milestones toward 50% efficient solar cell modules, 22nd European Photovoltaic Solar Energy Conference, Milan, Italy, Sept 2007.
http://www.udel.edu/iec/Publications/DARPA_22nd_EUPVSEC.pdf

2. Wu, J., Walukiewicz, W., et. al., Small band gap bowing in In1-xGaxN alloys, Appl. Phys. Lett. 80 (25), 4741-4743 (2002).

KEYWORDS: Photovoltaic, Solar Energy, InGaN, III-N, Nitrides, Epitaxy

SB082-053 TITLE: <u>Low-Cost Device Relevant Indium Gallium Nitride (InGaN) or Alternatives</u>

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: The goal of this research and development is to develop low-cost alternatives to InGaN epitaxy.

DESCRIPTION: While the telecommunications industry has demonstrated that costly epitaxy such as metal organic chemical vapor deposition (MOCVD) can penetrate high technology markets such as the cell phone industry, low cost alternatives will be required to penetrate low technology markets. The lighting industry is a key example. While InGaN is ideally suited for high efficiency lighting alternatives, it will not be able to compete with existing technology until the cost of manufacturing can be realistically measured in pennies-per-unit. Achieving this goal will require alternatives to the standard InGaN epitaxial techniques of MOCVD and molecular beam epitaxy (MBE).

This topic seeks a low cost alternative to MOCVD and MBE for the deposition of GaN and InGaN with materials quality roughly equivalent to MOCVD and MBE material. Specifically, material of sufficient quality for efficient light emitting diodes or photovoltaic applications is suitable. The proposed technique must be easily scalable such that it would provide quality material at less than half the cost of MOCVD at an equal production level. The preferred cost is less than a tenth that of MOCVD at an equal production level. Demonstration of the deposition technique as well as structural, optical and electrical characterization will be performed. Phase I must show the feasibility and scalability of the technique while Phase II will demonstrate the deposition of high quality material. The demonstration of various indium compositions and doping levels is highly desirable.

PHASE I: The offerer will conduct a feasibility study demonstrating the InGaN deposition technique with at least 5% indium content and predict materials quality in an optimized and scaled environment. The offerer will develop and document the design, decision path forward and testing plan that will lead to a viable manufacturing technology in Phase II.

PHASE II: The offerer will extend the InGaN deposition technique to validate the potential for high quality material. Fully characterized depositions will be demonstrated for no less than two indium compositions. The offerer will further provide a cost model and draft a preliminary path to large-scale commercial manufacturing of InGaN materials based on the technique.

PHASE III: This topic seeks a new manufacturing technology for a material system that spans both military and commercial markets. InGaN has been established as an essential component of high temperature electronics, blue lasers, solid state white lighting, high efficiency photovoltaics and radio frequency technologies. Thus the material impacts automobile electronics, optical storage (including next generation DVD technology), efficient lighting for commercial and home, solar energy conversion for portable and grid based electronics, wireless communications and radar. Developing a low cost manufacturing alternative for this material system will accelerate commercial availability of these technologies.

REFERENCES:
1. Mueller, A. H., Akhadov, E. A., Hoffbauer, M. A., Low-temperature growth of crystalline GaN films using energetic neutral atomic-beam lithography/epitaxy, Appl. Phys. Lett. 88, 041907 (2006).

2. Mukai, T., Recent progress in group-III nitride light-emitting diodes, IEEE J. of Selected Topics in Quantum Electronics 8 (2), 264-270 (2002).

3. Barnett, A. B., et. al., Milestones toward 50% efficient solar cell modules, 22nd European Photovoltaic Solar Energy Conference, Milan, Italy, Sept 2007.
http://www.udel.edu/iec/Publications/DARPA_22nd_EUPVSEC.pdf

KEYWORDS: InGaN, Epitaxy, Deposition, Manufacturing

SB082-054 TITLE: Explosion-Proof Solid State Lighting Fixture for Extreme Environments

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

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop an efficient explosion-proof lighting capability with reliable dimmable driver electronics for the shipboard naval environment ensuring long service life and the ability to withstand high-temperature operation under consistently high levels of continuous mechanical shock and vibration.

DESCRIPTION: Certain types of lighting aboard Naval vessels (such as the Symbol 48.2 incandescent lamp fixture) are required to operate continuously in high temperature, high vibration environments in the presence of inflammable vapors. The extreme operating environment causes the lamps in these fixtures to fail frequently which leads to high maintenance costs. The lamps themselves are also inefficient resulting in unsafe fixture surface temperatures and unnecessarily high energy consumption. Recent advances in Solid-State Lighting (high-power LEDs) together with the use of advanced coupling and luminaire optics have made these devices a highly desirable alternative to traditional lighting sources and offer the possibility of developing a robust alternative in current fixtures. The rated lifetimes of SSL devices are in the ~50,000 hour range rendering them potentially maintenance free. They are also substantially less vulnerable to damage through shock and vibration than incandescent lighting. The lighting solution developed under this program must incorporate SSL driver electronics which are themselves capable of such long-lived operation under these same harsh conditions. The resulting fixture must comply with the applicable MIL specs and standards for shipboard and submarine lighting systems while keeping unit costs at or near those of presently available commercial SSL drivers.

PHASE I: Develop a viable replacement for the symbol 48.2 lighting fixture. Determine the necessary architecture, design and construction criteria for the required LED driver electronics. Develop the monitoring, interface and control strategies that will prevent SSL junction overheating while delivering maximum possible lifetime light output. Investigate the possible advanced materials, devices, and thermal, mechanical and electrical design options which would lead to a viable shipboard fixture. Design circuitry that is capable of being qualified to the necessary standards and specifications to enable their use on surface and submarine naval vessels and to ensure compatibility with existing dimming technologies. Model the expected photometric performance of the design. Demonstrate that the lighting system developed will result in long-lived, robust, efficient, explosion-proof fixture capable of conforming to all the applicable MIL specifications referenced.

PHASE II: Build a prototype of the systems developed under Phase I. Measure photometric output and efficiency, and compare with the models produced in Phase I. Perform limited life testing under simulated field conditions to gather statistics on lamp life and quality of lighting over time. Collect data on performance under various powered conditions including dimming. Measure actual efficiency, current regulation, usable input-output voltage range, SSL protection action. Perform sufficient MIL qualification of the lighting fixture to enable an experimental integration and evaluation on an actual in-service naval vessel.

PHASE III DUAL USE APPLICATIONS: Reliable SSL lighting in general purpose lighting, harsh urban and industrial environments, remote location lighting and safety-related lighting applications.

REFERENCES:
1. MIL-DTL-16377H SUP 1B, "Detail Specification Fixtures, Lighting, and Associated Parts: Shipboard Use, General Specification For"

2. MIL-STD-1399-300A, "Interface Standard For Shipboard Systems Section 300A Electrical Power, Alternating Current (Metric)"

3. MIL-STD-461E "Department of Defense Interface Standard Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment"

4. U.S. Department of Energy, “Lifetime of White LEDs,” http://www.netl.doe.gov/ssl/PDFs/lifetimeWhiteLEDs_aug16_r1.pdf

5. U.S. Department of Energy, “Measuring Light Source Life,” http://www.netl.doe.gov/ssl/usingLeds/general_illumination_life_measuring.htm

6. Phillips, “Understanding power LED lifetime analysis,” http://www.lumileds.com/pdfs/WP12.pdf

7. DTI, “LED lighting technology: lessons from the USA,” http://www.oti.globalwatchonline.com/online_pdfs/36581MR.pdf

KEYWORDS: Explosion-Proof, SSL, LED, Lighting, Electronics, Reliability, Ballast

SB082-055 TITLE: A Spectrally Dynamic Berth Light for Active Circadian Cycle Management

TECHNOLOGY AREAS: Ground/Sea Vehicles, Human Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Design and build a berth light which will effectively reset the body clock for environments where the natural circadian rhythm is frequently disrupted.

DESCRIPTION: The fielded fluorescent berth lights presently installed in all naval vessels are simple lighting fixtures with a fixed spectral output. Recent research shows that there is a secondary spectral sensing system in the human eye which is closely tied to the regulation of the body’s circadian rhythm and which is particularly sensitive to the blue portion of the visible spectrum. By augmenting the lighting spectrum with controlled amounts of blue light, it may be possible to make more effective readjustments to an individual’s sleep schedule to better meet operational needs, reduce fatigue and improve safety. While the primary focus of this research is the development of the circadian modification system in the form of a berth light and its associated controls, it is mandatory that the proposed lighting device also be a cost-effective and serviceable replacement to the existing fielded lighting fixtures, and that it provides the same or better quality of general lighting as defined by the applicable specification documents referenced. The use of long-life Solid-State Lighting (SSL) devices is recommended but not mandatory.

PHASE I: Demonstrate the feasibility of a berth light fixture which has a spectral output designed to stimulate and the body's circadian photoreceptors to effect a resetting of the body clock. The design should include a simple control interface designed for ease of use. In addition to the circadian modification feature, an analysis of the lighting output should be performed to show that the proposed design is capable of providing general illumination consistent with the specifications defining the devices it replaces.

PHASE II: Develop a working prototype berth light based on the results of Phase I. Demonstrate that the proposed system is also a fully functional lighting replacement to the existing berth light which is specified in Military Specification: MIL-F-16377/17. Conduct limited testing to demonstrate conformance of the prototype with the applicable specifications and standards referenced regarding electrical interfaces, EMI, shock, vibration, etc.

PHASE III: The applications of this technology span both the military and commercial areas. Transportation and public safety would be directly impacted by reducing operator fatigue for long-haul trucking. All maritime areas would be impacted including Coast Guard, merchant marine, and DoD surface and submarine operations. Business travelers can use portable commercialized versions of the technology to manage time-zone changes more effectively.

REFERENCES:
1. Brainard, G.C., et al. 2001. Action spectrum for melatonin regulation in humans: Evidence for a novel circadian photoreceptor. Journal of Neuroscience 21(6) (Aug. 15):6405-6412.

2. Lockley, S.W., G.C. Brainard, and C.A. Czeisler. High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light. Journal of Clinical Endocrinology & Metabolism 88 (9), September 2003:4502-4505.

3. Berson, D.M., F.A. Dunn, and M. Takao. Phototransduction by retinal ganglion cells that set the circadian clock. Science 295(5557) (Feb. 8 2002):1070-1073.

4. "Human Factors in Ship Design", The Society of Naval Architects and Marine Engineers. http://www.sname.org/committees/tech_ops/O38/hfsd.doc

5. MIL-F-16377/17 Specification Sheet, Detail Lighting for Berths.

6. MIL-DTL-16377H (SH) Shipboard Lighting Detail.

7. MIL -STD-1399(section 300).

8. MIL -STD-461E.

KEYWORDS: Circadian Cycles, Sleep, Fatigue, LED, Solid-State Lighting, Human Factors, Maritime Berthing

SB082-056 TITLE: Mobile Offshore Platform for Wind Turbine Power Generation

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop a free floating mobile offshore platform that can keep station and support a large wind turbine to meet future DOD sustainable power generation needs.

DESCRIPTION: The military is forced to base troops and equipment in hostile environments. To supply power, the DoD must ship fuel to tactical areas. It is common that transporting the fuel requires as much or more energy than the fuel provides. To solve this problem, the DoD has invested substantial resources in developing renewable sources of energy to mitigate the exorbitant cost of transporting fuel. The two most prominent sources for renewable energy are solar and wind energy. The problems with solar energy are: 1) under the best conditions, it is only available for, at most, half of the day; and 2) power requirements, necessitate large-scale (permanent) installations that require substantial amounts of area to deploy. Extracting energy via wind generators also presents challenges; only certain geographic areas can provide the sustained wind speeds required to generate power, and like solar power, large (permanent) land-based turbines require a substantial amount of area. These disadvantages can be eliminated with offshore wind turbines. There are a plethora of maritime locations with high-velocity sustained winds, and the large area required for installation can easily be provided. They are also far less susceptible to attack in the ocean. The current limitation is that offshore wind turbines are permanently installed on the ocean floor and are not designed to ever be easily moved.

The proposed SBIR topic is to develop a floating platform that can be relocated and can support a large offshore wind turbine. A large floating offshore wind turbine can support the DoD energy generation requirements in remote locations, or support disaster relief efforts where local power generation has been destroyed and/or the fuel supply has been disrupted. When the DoD no longer needs the power generation capacity, the systems could be removed and transferred to another location. Moreover, floating wind turbines can be installed in water depths that traditional pile-mounted systems, could not accommodate and, in theory, could support much larger wind turbines as well.

The problem with floating offshore wind turbine systems is that they are inherently unstable. The turbine and generators, which represent the majority of the system weight, are mounted at the highest point on the structure, creating a high center of mass off the water and making it very difficult to transport and operate in the open ocean. Additionally, traditional, offshore platforms have relied on complex mooring systems in order to maintain stability and position. These mooring systems are permanent and undesirable for the envisioned system which requires mobility. The goal of this project would be to develop a novel offshore platform that would be able to support the wind turbine during transit, and would not use moorings during operation. Concepts could include, but are not limited to, novel hull forms, innovative operational techniques, or variable geometry platforms that could raise and lower the turbine for transit, or using collapsing blades or structures. In order to maintain station, the system should use a combination of active thrusters, variable hull-form geometry, or other innovative techniques. The system must keep position within a 25 ft radius, to avoid collisions, when distributed in a farm configuration. Additionally, the system can be towed at a speed of at least 7 knots, operate in year long intervals with only routine maintenance, in up to 50 mph winds, and survive 70 mph winds and a sea state 9.

PHASE I: Prepare a feasibility study based on first principles and computational modeling to develop an offshore platform that can support a wind turbine and maintain station, without the use of mooring lines. The ultimate Phase I goal is to evaluate the concept, in order to determine if large mobile offshore wind turbines can be used to support future DOD power generation needs.

PHASE II: The concept from Phase I will be finalized. Engineering, testing, modeling, and validation of the design will be performed. A large-scale model test with wind and waves would be used to test the hydrodynamic performance of the system. This test would be used to demonstrate the benefits of mobile offshore wind turbines.

PHASE III: The commercial applications for this technology are plentiful. It would allow US companies to install sustainable power generation systems in developing countries, without the fear of nationalization. Moreover, by placing the large capital assets offshore, one could also dramatically reduce their susceptibility to terrorist threats, better securing the investment. The need for sustainable power in developing countries is overlooked because of the high initial investment that is required. Developing countries lack the organization and the capital to procure such systems. Furthermore, corporate entities do not want to undertake the enormous risk of building such a large capital asset in a location where it could be destroyed by terrorists, nationalized, and/or become unfeasible due to changes in the local economy. If at any point a mobile wind turbine is no longer profitable or if it is more profitable elsewhere in the world, it can be moved.

REFERENCES:
1. Sclavounos, Pual, Et.Al. “Floating Offshore Wind Turbines: Responses in a Seastate Pareto Optimal Designs and Economic Assessment”, MIT Oct. 2007.

2. US Wind Power Maps.
http://www.windpowermaps.org/default.asp

KEYWORDS: Wind Turbine, Wind Energy, Offshore Platform, Sustainable Power, Renewable Sources of Energy, Station Keeping

SB082-057 TITLE: Non-Line-of-Sight Ultraviolet (UV) Communication Networks

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

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: Undertake a Phase I feasibility study to investigate the development of a mobile, ad-hoc non-line-of-sight free-space optical communication multi-user network that exploits the scattering properties of UV light.

DESCRIPTION: Existing free-space visible and infrared optical communication strategies require an unobstructed line-of-sight between a single transmitter and receiver. With highly directional line-of-sight links, developing optical communication networks is problematic. In addition, precise pointing, acquisition and tracking are required, with aerosols and particulates absorbing laser energy at these frequencies. However, at UV frequencies laser energy is scattered more than it is absorbed by the atmosphere. Furthermore, in the UV band from 220-280 nm the Earth's ozone layer absorbs most UV radiation incident from the sun, so that there is little or no naturally occurring background radiation in this UV band. Here we propose to exploit this natural scattering and lack of background radiation to create an optical bubble of UV light with a diameter of 1-4 km, within which multi-user ad-hoc non-line-of-sight UV communication would be possible. Exploiting this phenomenon requires the development of new, novel multi-user networking strategies, protocols, coding schemes and modulation formats tailored to optical communications requirements. The existence of such a network would enable seamless communication in radio frequency (RF) denied hostile environments. The UV non-line-of-sight (NLOS) communications physical layer is quite different from radio frequency (RF). Existing RF signal waveforms and multi-access algorithms are designed for a channel that is described by Gaussian or Rayleigh noise statistics and continuous waveforms. In contrast, optical communications at UV frequencies are described by Poisson statistics, which presents the receivers with signals that are highly variable from bit to bit (fast fading), and are made up of quantized (discontinuous) photon streams. RF networks are based on links with a 1/R2 range dependence on power, whereas UV communications links have a 1/R dependence. These unique features demand new approaches to physical layer (PHY) medium access control (MAC), and network layer algorithms.

PHASE I: Prepare a feasibility study for a mobile, ad-hoc non-line-of-sight (NLOS) multi-user UV communications network strategy. During the first phase, the performer will propose coding schemes, protocols and algorithms required to support a 20-node network.

Assuming commercial off-the-shelf representative NLOS UV hardware, the following must be developed and modeled:
1. Network control algorithms with spatial awareness of users nodes and directional transceivers for spatial reuse of bandwidth and reduced power consumption.
2. Network protocols that provide mobile ad hoc network connectivity in an efficient manner to minimize overhead and provide packet latencies appropriate for voice over networks of many (>10) hops.
3. Formal design of the networking coding schemes and protocols will be developed and a report generated. As part of the final report, plans for Phase II will be proposed. Intent of study is to demonstrate the feasibility of a 20-node network with maximum data rates from 28.8 kbps - 512 kbps and NLOS transmission distances from 500m - 2000m.

PHASE II: The design from Phase I will be finalized. All appropriate engineering proof of concept work and validation of design issues will be performed.

At a minimum, the following must be developed and modeled in detail:
1. UV hardware and multi-access algorithms that provide mobile NLOS UV communication multi-user links.
2. Multi-hop networking capability with demonstration of a mobile convoy scenario.
3. Modeling of UV hardware bit-rate-range capability required for link closure.
4. Modeling of waveforms and PHY/MAC layer algorithms consistent with UV phenomenology.
5. Efficient directional network protocols to provide extended coverage with acceptable voice packet loss and latency.
6. A critical design review will be preformed to finalize the network model design to verify the viability of the delivered protocols and network coding schemes.

PHASE III: There are both military and commercial applications of this technology for scenarios where RF communication is not feasible.

REFERENCES:
1. Dwivedi, A. Critical Technology Gaps and Potential Solutions for Mobile Free Space Optical Networking. Military Communications Conference, 2006. MILCOM 2006: 1-7.

2. Akella, J., Yuksel, M., Kalyanaraman, S. Multi-channel Communication in Free-Space Optical Networks for the Last-mile. LANMAN 2007. 15th IEEE Workshop on Local & Metropolitan Area Networks, 2007: 43-48.

KEYWORDS: Ultra-Violet, Non-Line-of-Sight, Optical Communications, Networking

SB082-058 TITLE: Mission Assured Networking (MAN)

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop an approach to autonomously map administrative, business, and war fighting missions to the required networks and information systems in highly dynamic environment.

DESCRIPTION: MAN is defined as a capability to map an organizations mission or mission critical tasks at any point in time to the required information, systems, and/or users required to complete that mission.

As an example, a MAN-enabled alert system would monitor, correlate, and notify operations and communications professionals of potentially impacted military operations as well as the causal network events that rely on potential or actual degraded systems rather than just indicating the network or system failures.

Proposed solutions may require operation at a very high granularity – perhaps at the packet or message level, rather than at the user or application level. They should also be autonomic or semi-autonomic systems that map their mission to the underlying infrastructure in highly dynamic coevolutionary domains where users, networks, and missions change over time.

In addition to critical event detection and improving situational awareness, this capability is required prior to developing autonomic defense and management systems. These systems will determine when an event has occurred that impacts DoD missions, then develop potential courses of action that are run through mission impact analysis, so an informed course of action can be selected that minimizes harmful impact to DoD missions.

The DoD has developed an overarching concept known as Net-Centric Warfare (NCW), which is the implementation of information age technology and concepts into the U.S. military. The DoD defines NCW as information superiority enabled concept of operations that generates increased combat power by networking sensors, decision makers, and shooters as well as administrative and business processes to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability, and a degree of self synchronization. In essence, NCW translates information superiority into combat power by effectively linking knowledgeable entities.

To facilitate NCW, DoD operators and leaders must understand the relationships that exist between mission and business requirements and the information that supports the mission.

Key challenges to MAN include:
• There is a lack of basic science on information utility as it pertains to organizational missions and information technology. The result is commercial systems that label entire systems, users, or applications as mission critical at all phases of operations. This results in a gross overestimate of worth and over provisioning of resources to the wrong activity at the wrong time.
• Organizational missions and tasks, as well as the information and communications infrastructure are highly dynamic. Not only do missions change over time, but priorities change within phases of missions. Network devices, links, data, applications, configurations, and users are constantly changing.
• The DoD operates in a hostile environment (both physically and logically), where opponents are not only seeking to understand what the organization is doing, but also prevent the organization from achieving its goals. This spectrum of hostilities may run from espionage to physical destruction. Understanding the potential or actual impact of these threats to a mission is critical to mission planning and accomplishment.
• Advanced information technology and network-centric operations have pushed collaboration and problem solving out of the traditional hierarchical command and control structure. Organizational collaboration occurs as an informal mesh of low-level collaborating entities, rather than through the traditional, hierarchical formal command and control structure. This evolution may eliminate centralized control and understanding of the environment and mission in favor of a more rapid, peer-to-peer collaboration model.

As DoD evolves NCW, it will continue to face two fundamental constraints:
1. A lack of bandwidth especially in tactical environments. While a general solution is to overprovision, this may be excessively costly or unavailable in some environments. Additionally, the bandwidth may be unavailable due to malicious loss of critical nodes or links, resulting in a dynamic reallocation of priorities. Prioritizing mission traffic based on mission impact of traffic would greatly help the constrained warfighter.
2. A lack of skilled personnel, so any solution should not be manpower intensive to manage. Solutions should be autonomous, or semi-autonomous.

PHASE I: Conduct a feasibility study on the design and development of a bottom-up system which would map administrative, business, and warfighting mission requirements to the supporting networks and information systems. Propose a MAN-utility model for implementation.

PHASE II: Develop a working prototype and utility model that maps administrative, business, and war fighting mission requirements to the supporting networks and information systems to solve a specific military problem based on the Phase I feasibility study. All appropriate engineering testing and validation of design issues will be performed.

PHASE III: MAN-enabled protocols, applications, and routing devices would greatly improve communications, situational awareness, and planning in commercial, government, and DoD information-enabled systems.

REFERENCES:
1. Grimailia, M.R. and L.W. Fortson. Towards an Information Asset-Based Defensive Cyber Damage Assessment Process, Computational Intelligence in Security and Defense Applications, 2007. CISDA 2007. IEEE Symposium on 1-5 April. ISBN: 1-4244-0700-1.

2. Department of Defense Architectural Framework (DODAF), http://www.defenselink.mil/cio-nii/docs/DoDAF_Volume_I.pdf, DoDAF 1.5 Volume 1, Definitions and Guidelines, 23 April 2007.

3. J. Aczel and Z. Daroczy. "On Measures of Information and Their Characterization," Academic Press, 1975.

KEYWORDS: Information Systems, NetCetric Operations, Mission Priority

SB082-059 TITLE: Continuous Detonation Rocket and Air Breathing Engines

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: N/A

OBJECTIVE: Identify and develop innovative propulsion systems based on Continuous Detonation Combustion. Develop a mechanically simple way to capture the benefits of constant volume combustion using continuous detonation. These devices differ from more traditional Pulse Detonation Engines in that the detonation wave travels continuously in an annulus. Proposals are sought for innovative Continuous Detonation Rocket Engine (CDRE) concepts. Also of interest would be CDRE concepts that could also be operated in an air breathing mode (CDE).

DESCRIPTION: DARPA is interested in developing the technologies necessary for the successful demonstration of CDRE and CDE operation. Potential applications include rocket engines, missile engines, innovative turbo machinery/CDE engines, novel afterburners, combined cycle engines and power generation devices.

PHASE I: Conduct an analysis and feasibility study of potential scalable approaches for developing CDRE's. Emphasis should be placed on innovative technology and system concepts which offer the potential of efficient, high frequency, reliable and long duration operation. Initial analysis should focus on rocket cycles. Additionally, concepts which can be adapted to air breathing operation are also desired. Identify key technologies and sub-systems requiring development and present a credible plan to accomplish these tasks.

PHASE II: Develop the technologies and sub-systems identified in Phase I and demonstrate CDRE operation with a test article configuration that is traceable to useful Military and Commercial applications. It is also highly desirable to demonstrate air breathing operation (CDE).

PHASE III: The technology developed under this SBIR can be used in military and civilian commercial applications including rocket and air breathing powered vehicles, and power generation devices.

REFERENCES:
1. J. A. Nicholls, and R. E. Cullen, "The Feasibility of a Rotating Detonation Wave Rocket Motor". The University of Michigan Department of Aeronautical and Astronautical Engineering, Technical Documentary Report No. RPL-TDR-64-113, 1964.

2. Fedor A. Bykovskii, and Evgenii F. Verdenikov, "Continuous Detonation of a Subsonic Flow of Propellant", Combustion Explosion and Shock Waves, Vol. 39, No. 3, pp. 323-334, 2003.

KEYWORDS: Pulse Detonation Engines, Continuous Detonation Engines, Detonation, Propulsion

SB082-060 TITLE: Wireless Avionics Architecture for Payload Delivery Launch Systems

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Space Platforms

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study to develop and flight-demonstrate a wireless data communication system for a very low cost, operationally responsive expendable launch system for orbital injection of payloads. Address the technical, cost risks and benefits compared to traditional wire-harness and electrical/data inter-stage interface architectures.

DESCRIPTION: Ground and Air payload delivery launch systems could benefit from the technical advances made in ground-based wireless communication technology. Currently, the weight of wire harnesses, brackets, mounting hardware, avionics connectors and stage connect interfaces represent a significant portion of a typical launch vehicle. During the development phase of a launch vehicle, considerable effort is required during design to accommodate the constraints imposed by wire harnesses such as structural pass-throughs, thermal/vibration limits, and minimum turn radii. Qualification of the wire-based architecture is also expensive and time consuming normally requiring duplicate builds and hipot testing. Last, there is risk associated with potential cross-wiring and in-flight launch/in-space environment connection failures.

This topic seeks to mature wireless communication between launch system avionics components including flight computers, navigation systems, actuators, sensors, etc, with the goals of reducing launch system:
- Weight.
- Development cost.
- Operational cost.
- Development risk.
- Operational risk.

PHASE I: Prepare a feasibility study for the development and demonstration of a wireless avionics architecture for a payload delivery launch system. The architecture should include all aspects of a launch system including central command (such as a flight processor), navigation, control (actuation), and sensors. Proposals with a path leading to a flight demonstration are preferred. However, given the limited flight opportunities, proposals leading to a ground demonstration are acceptable as long as the proposal clearly addresses the limitations of the architecture upon demonstration. Proposals should also address architecture susceptibility to external and internal noise and methods to mitigate it. As part of the final report, plans for Phase II will be proposed.

PHASE II: Ground and/or flight demonstration of the wireless avionics architecture. All appropriate engineering testing and validation of design issues will be performed. The performance of the architecture shall be assessed and documented.

PHASE III: There is both military and commercial application of this technology in space launch, sounding rocket, and ballistic missile defense applications. This technology is also applicable to the growing interest in commercial space tourism with exo-atmospheric vehicles. Commercial and military satellite systems could be extended with this technology.

REFERENCES:
1. “Modular, Reconfigurable, High-energy Technology Development”, Connie Harrington and Joe Howell, 2006, NASA Marshall Space Flight Center, Huntsville AL.

2. “Modular High-Energy Systems for Solar Power Satellites”, Howell, Joe T.; Carrington, Connie K.; Marzwell, Neville I.; Mankins, John C.; [2006]; NASA Marshall Space Flight Center, Huntsville, AL, International Space Development Conference, 4-7 May 2006, Los Angeles, CA, USA.

3. “Aeronautics and Space Report of the President”, Fiscal Year 2002 Activities, National Aeronautics and Space Administration, Washington, DC.

4. “Modular Wireless Avionics System for Autonomous UAVs.”, Schinstock, Dale E., and Thompson, J. Garth, 2006, National Aeronautics and Space Administration.

5. “WIRELESS AVIONICS”, J. Ned Yelverton, Seabrook, Texas, Digital Avionics Systems Conference, 1995.

KEYWORDS: Wireless, Avionics, Launch, Vehicle, System, Harness, Connector, Navigation, Control.

SB082-061 TITLE: <u>Transformational Close Air Support</u>

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

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study to identify and develop revolutionary capabilities that allow front-line soldiers to rely on, and rapidly and effectively direct, airborne delivery of conventional and precision guided munitions.

DESCRIPTION: Changing geopolitical conditions and warfighting technologies provide increasing advantages to the employment of small-unit in distributed operations. However, such lightly equipped forces in many scenarios still face considerable risk of being overwhelmed by larger and more powerful enemy forces armed with conventional and non-traditional weapons. At the same time, unconventional forces pose new challenges even to conventional forces. One way to reduce these vulnerabilities is to rely to a greater extent on indirect fires from airborne platforms. Airborne delivery of munitions in close proximity to friendly forces is a particularly challenging mission called Close Air Support (CAS). Among the difficulties that limit the use of CAS are the complex command and control procedures involved; the sheer bulk of equipment required for ground directors; and a diversity of interfaces between delivery aircraft, weapons, controllers, and commanders. CAS is also constrained by the cost, availability, transit time, precision and effects of existing weapons and aircraft. Incremental improvements are under way to address these issues through reduced weight ground director equipment, digital command and control concepts, smaller and more precise weapons, improved sensors, and new CAS platforms. The intent of this SBIR is to identify novel approaches to CAS that fundamentally improve its effectiveness and economy of use. Predictive methods, automated employment tools, enhanced communications, collaborative operating concepts, and new or improved weapons and platforms could all potentially provide a leap-ahead improvement for challenging threat and operating environments. Concepts that reduce or eliminate specialized training and equipment will further enhance the utilization of improved CAS capabilities. Measures that improve the trust of warfighters and the public in new CAS concepts and help overcome organizational constraints are valuable as well.

PHASE I: Prepare a feasibility study for CAS enhancements. During the first phase, the performer will propose one or more CAS enhancements. Formal design of the concept will be performed and a preliminary design review and report will be generated. As part of the final report, plans for Phase II will be proposed.

PHASE II: The design from Phase I will be finalized. All appropriate engineering testing and validation of design issues will be performed. A critical design review will be performing to finalize the design and a prototype unit will be manufactured and tested.

PHASE III DUAL USE APPLICATIONS: Enhanced CAS capabilities will improve the overall effectiveness of ground and littoral combat operations by improving the survivability, maneuverability and flexibility of ground forces through greater reliance on CAS. With greater reliance on CAS, units will be less dependent on organic and supporting ground fires and thus lighter and less restricted in their movements. While there is no direct civil application of CAS, CAS enhancements are also expected to apply to aircraft in support to law enforcement, security, and agriculture. Specific enhancements are also likely to be valuable in a wide range of civil applications characterized by responsive specialized services dispatched to support a broad customer base with unpredictable needs, such as disaster response or infrastructure repair.

REFERENCES:

1. “Operation Anaconda: An Airpower Perspective - Close air support during Operation Anaconda,” United States Air Force, 2005 (http://www.af.mil/library/posture/Anaconda_Unclassified.pdf).

2. “Next-Generation Gunship Analysis of Alternatives Final Report – Volume I,” Rand, 2004.

3. Grant, Rebecca, “The Clash About CAS,” Air Force Magazine, Jan 2003

KEYWORDS: Close Air Support, Indirect Fires, Designation Equipment, Weapons Control

SB082-062 TITLE: <u>Leap-Ahead Control Theoretic Applications</u>

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: Prepare a Phase I feasibility study to investigate non-linear, adaptive, digital, and other innovations that overcome the limitations of conventional control technologies.

DESCRIPTION: Control theory today generally stands as it did 50 years ago. The fundamental concepts of feedback, stability, and even adaptive control have not changed significantly since; improvements have largely been driven by improved technologies for sensing, processing, and actuating closed-loop systems. Many military applications depend on the ability to maximize the use of limited control authority in the presence of uncertain plant characteristics and external disturbances. Design processes are limited by the ability of engineers and mathematicians to manipulate differential equations (linear and special case non-linear) to provide a suitable control law approximation that can be proven to be sufficiently stable to meet requirements. While optimized design techniques have advanced considerably, many are difficult to validate. Digital control system design is generally focused on avoiding the limitations of binary representations while replicating the analog control concepts developed before the widespread use of computers. While control systems are able to determine and optimize a trajectory better than humans, humans outperform on less structured and more practical applications such as route finding or aggressive aircraft maneuvering.

PHASE I: Prepare a feasibility study and design for control innovations.

PHASE II: Demonstrate the feasibility and effectiveness of control innovations for military applications.

PHASE III: Leap-ahead control theoretic applications are extremely relevant to improved operation and automation of military vehicles and weapons. Advances will also be of great value to civil applications of vehicle operations and process control.

REFERENCES:
1. Brogan, William L. Modern Control Theory. 3rd ed. Englewood Cliffs, N.J.: Prentice-Hall, 1991.

2. Bertsekas, D. P. Dynamic Programming and Optimal Control. 2nd ed. Belmont, Mass.: Athena Scientific, 2000.

KEYWORDS: Control, Feedback

SB082-063 TITLE: <u>Energy Rejection Systems for Very High Altitude Aircraft</u>

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: N/A

OBJECTIVE: Identify and develop innovative low drag, light-weight energy rejection systems suitable for use on very high altitude aircraft.

DESCRIPTION: DARPA is interested in developing the technologies necessary for deploying very high altitude aircraft having long endurance. One key technology required for this capability is the ability to reject waste heat from a variety of sources (from engines to sensors) at very high altitudes (85-100kft) from a low-speed, very low drag aircraft. This cooling system must be compact, scalable, and capable of operating at both low and extreme altitudes. The stringent requirements for this type of aircraft dictate solutions having very low drag and weight.

PHASE I: Conduct an analysis and feasibility study of potential scalable approaches to provide low drag, low weight cooling (at operational environments from 85-100kft) for a low-speed aircraft (< 100 knots). Demonstrate that the proposed system is scalable, and is capable of the reliability, and environmental requirements necessary to reject 5-100kW of heat continuously for greater than 20 hours for the intended aircraft cruise altitude and speed. Identify key materials and sub-systems requiring development and present a credible plan to accomplish these tasks.

PHASE II: Develop the materials and sub-systems identified in Phase I and demonstrate the cooling performance with a 50kW thermal load for >20 hours in a simulated very high altitude (~90kft) pressure and temperature environment for a low-speed aircraft (<100 knots).

PHASE III: The technology developed under this SBIR can be used in military and civilian commercial applications such as emergency power and atmospheric research.

REFERENCES:
1. “HALE Thermal Balance”, Petkus, Edward P., Gallington, Roger W., SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987.

2. “Skin as Radiator-Passive Thermal Management for High-Altitude, Long-Endurance UAVs”, A. L. Phillips and Kevin L. Wert, 34th Intersociety Energy Conversion Engineering Conference, August 1999, Vancouver, BC, CANADA.

3. “Propulsion Selection for 85kft Remotely Piloted Atmospheric Science Aircraft”, D. J. Bents et al., Association for Unmanned Vehicle Systems Orlando, Florida, July 16-19, 1996.

4. “Uninhabited Air Vehicles: Enabling Science for Military Systems,” National Materials Advisory Board, Aeronautics and Space Engineering Board. National Academies Press, 2000.

KEYWORDS: Very High Altitude, Propulsion, Cooling, Aircraft

SB082-064 TITLE: Metal Hydride Energy Sources for Very High Altitude Aircraft Propulsion

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: N/A

OBJECTIVE: Identify and develop innovative metal hydride energy sources for very high altitude, long endurance aircraft propulsion.

DESCRIPTION: DARPA is interested in developing the technologies necessary for deploying a very high altitude aircraft capable of 12-20 hour endurance that can be stored in a sealed container for extended periods. One key technology required for this capability is a stable energy source that can power a propulsion system for sustained operations at very high altitudes (85-100kft). This energy source must be stably stored for periods of a year and yet deliver the energy and power required for the propulsion system of a High Altitude Long Endurance (HALE) aircraft. The stringent weight and volume requirements for this type of aircraft dictate solutions having high specific energy and power. Of special interest are propulsion systems that can survive and operate after extended periods at extremely cold temperatures. Based on previous DARPA analyses, the most promising candidate energy sources are various types of metal hydrides that can be oxidized at high efficiency in the thin operational atmosphere to produce either heat (to directly drive heat engines) or electricity (to drive electric motors).

PHASE I: Conduct an analysis and feasibility study of potential approaches to oxidize various metal hydride compounds (at operational environments from 85-100kft) to produce either the 100kW of thermal energy (@ >1000K) or the 35 kW of electrical energy necessary to drive propulsion engines. Demonstrate through analysis that the proposed energy system has the stability and reliability to provide the required power to the propulsion system on an extreme HALE aircraft with 12-20 hour endurance that must be stored for one year. Perform a first order design with calculated specific weight and power of the complete system, identify key materials and sub-systems requiring development, and present a credible plan to accomplish these tasks.

PHASE II: Develop the materials and sub-systems identified in Phase I and demonstrate a one-tenth scale proof-of-concept laboratory energy supply system capable of both starting and continuous operation for more than 12 hours in simulated very high altitude (~90kft) pressure and temperature environment for a low-speed aircraft (<150 knots).

PHASE III: The technology developed under this SBIR can be used in military and civilian commercial applications such as emergency power and atmospheric research.

REFERENCES:
1. “Thermophysical Properties of Lithium Hydride, Deuteride, and Tritide and of their Solutions with Lithium”, by E. E. Shpil'rain, S. J. Amoretty, K. A. Yakimovich, T. N. Mel'nikova, Alexandreya Polishchuk, Springer, 1987.

2. “Propellants and Combustion,” Aerospace America, pp. 56-57, December 2006.

3. “Pyrolysis And Combustion Of Lithium Aluminum Hydride,” McLain,William H.; Honea, Franklin I., Available in DTIC, Denver Research Institute, Colorado, May, 1969.

4. ”Combustion Characteristics of Aluminum Hydride at Elevated Pressure and Temperature”, T. Bazyn; R. Eyer; H. Krier; N. Glumac, Journal of Propulsion and Power, Vol.20 No.3, pp. 427-431, 2004.

KEYWORDS: Very High Altitude, Low-Oxygen Environment, Energy, Propulsion, Aircraft