DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)
13.1 Small Business Innovation Research (SBIR)
Proposal Submission Instructions

1.1 Introduction:

DARPA's mission is to prevent technological surprise for the United States and to create technological surprise for its adversaries. The DARPA SBIR and STTR Programs are designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk approaches to address existing and emerging national security threats; thereby supporting DARPA's overall strategy to bridge the gap between fundamental discoveries and the provision of new military capabilities.

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

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Attention: DIRO/SBPO
675 North Randolph Street
Arlington, VA 22203-2114
(703) 526-4170
Home Page http://www.darpa.mil/Opportunities/SBIR_STTR/SBIR_STTR.aspx

Offerors responding to the DARPA topics must follow all the instructions provided in the DoD Program Solicitation. Specific DARPA requirements in addition to or that deviate from the DoD Program Solicitation are provided below and reference the appropriate section of the DoD Solicitation.

SPECIFIC DARPA REQUIREMENTS

The solicitation has been EXTENSIVELY rewritten and follows the changes of the SBIR reauthorization. Please read the entire DoD solicitation and DARPA instructions carefully prior to submitting your proposal. Please go to http://content.govdelivery.com/bulletins/gd/USSBA-4cada5# to read the SBIR Policy Directive issued by the Small Business Administration.

3.0 DEFINITIONS

3.3 Export Control

The following will apply to all projects with military or dual-use applications that develop beyond fundamental research (basic and applied research ordinarily published and shared broadly within the scientific community):

(1) The Contractor shall comply with all U. S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of this contract. In the absence of available license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of (including deemed exports) hardware, technical data, and software, or for the provision of technical assistance.

(2) The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site

at any Government installation (whether in or outside the United States), where the foreign person will have access to export-controlled technologies, including technical data or software.

(3) The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.

(4) The Contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors.

Please visit http://www.pmddtc.state.gov/regulations_laws/itar.html for more detailed information regarding ITAR requirements.

3.4 Foreign National

ALL offerors proposing to use foreign nationals MUST follow Section 5.4.c.(8) of the DoD Program Solicitation and disclose this information regardless of whether the topic is subject to ITAR restrictions.

4.0 PROPOSAL FUNDAMENTALS

4.6 Classified Proposals

DARPA topics are unclassified; however, the subject matter may be considered to be a "critical technology" and therefore subject to ITAR restrictions. See **Export Control** requirements below in Section 3.3.

4.10 Debriefing

DARPA will provide a debriefing to the offeror in accordance with FAR Subpart 15.5. The notification letter will provide instructions for requesting a proposal debriefing. Small Businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the proposal number and topic number referenced. All communication from the DARPA will originate from the sbir@darpa.mil e-mail address. Please white-list this address in your company's spam filters to ensure timely receipt of communications from our office.

4.23 Phase I Proposal Checklist:

The following criteria must be met or your proposal may be REJECTED.

____1. Include a header with company name, proposal number and topic number to each page of your technical volume.
____2. Include tasks to be completed during the option period and include the costs in the cost volume.
____3. Break out subcontractor, material and travel costs in detail. Use the "Explanatory Material Field" in the DoD Cost Volume worksheet for this information, if necessary.
____4. The base effort does not exceed $100,000 and six months and the option does not exceed $50,000 and four months. The costs for the base and option are clearly separate, and identified on the Proposal Cover Sheet, in the cost volume, and in the statement of work section of the technical volume.
____5. The technical volume does not exceed twenty (20) pages. Any page beyond 20 will be redacted prior to evaluations.
____6. Upload the Volume 1: Proposal Cover Sheet; Volume 2: Technical Volume; Volume 3: Cost Volume; and Volume 4: Company Commercialization Report electronically through the DoD submission site by 6:00 am ET, 16 January 2013.
____7. After uploading your file on the DoD submission site, review it to ensure that all pages have transferred correctly and do not contain unreadable characters. Contact the DoD Help Desk immediately with any problems.

Notification of Proposal Receipt

After the solicitation closing date, the person listed as the “Corporate Official” on the Proposal Coversheet will receive an e-mail with instructions for retrieving a proposal acknowledgement receipt from the DARPA SBIR/STTR Information Portal.

Information on Proposal Status

Once the source selection is complete, the person listed as the “Corporate Official” on the Proposal Coversheet will receive an email with instructions for retrieving a letter of selection or non-selection from the DARPA SBIR/STTR Information Portal.

5.0 PHASE I PROPOSAL

Phase I Option

DARPA has implemented the use of a Phase I Option that may be exercised to fund interim Phase I activities while a Phase II contract is being negotiated. Only Phase I companies selected for Phase II will be eligible to exercise the Phase I Option. The Phase I Option covers activities over a period of up to four months and should describe appropriate initial Phase II activities that may lead to the successful demonstration of a product or technology. The Technical Volume for the Phase I Option counts toward the 20-page limit for the Technical Volume.

A Phase I Cost Volume ($150,000 maximum) must be submitted in detail online via the DoD SBIR/STTR submission system. Proposers that participate in this solicitation must complete the Phase I Cost Volume, not to exceed the maximum dollar amount of $100,000, and a Phase I Option Cost Volume, not to exceed the maximum dollar amount of $50,000. Phase I awards and options are subject to the availability of funds.

Offerors are REQUIRED to use the online Cost Volume for the Phase I and Phase I Option costs (available on the DoD SBIR/STTR submission site).

Technical Assistance

In accordance with the Small Business Act (15 U.S.C. 632), DARPA will authorize the recipient of a Phase I SBIR award to purchase technical assistance services, such as access to a network of scientists and engineers engaged in a wide range of technologies, or access to technical and business literature available through on-line data bases, for the purpose of assisting such concerns in—

A. making better technical decisions concerning such projects;
B. solving technical problems which arise during the conduct of such projects;
C. minimizing technical risks associated with such projects; and
D. developing and commercializing new commercial products and processes resulting from such projects.

If you are interested in proposing use of a vendor for technical assistance, you must provide a cost breakdown under “Other Direct Costs (ODCs)” of the Cost Volume and provide a one page description of the vendor you will use and the technical assistance you will receive. The proposed amount may not exceed $5,000 and the description should be included as the LAST page of the Technical Volume. This description will not count against the 20-page limit and will NOT be evaluated. Approval of technical assistance is **not guaranteed** and is subject to review of the contracting officer.

Human or Animal Subject Research

DARPA discourages offerors from proposing to conduct Human or Animal Subject Research during Phase 1 due to the significant lead time required to prepare the documentation and obtain approval, which will delay the Phase 1 award.

5.3 (c) (6) Commercialization Strategy
DARPA is equally interested in dual use commercialization of SBIR project results to the U.S. military, the private sector market, or both, and expects explicit discussion of key activities to achieve this result in the commercialization strategy part of the proposal. The discussion should include identification of the problem, need, or requirement relevant to a Department of Defense application and/or a private sector application that the SBIR project results would address; a description of how wide-spread and significant the problem, need, or requirement is; and identification of the potential DoD end-users, Federal customers, and/or private sector customers who would likely use the technology.

Technology commercialization and transition from Research and Development activities to fielded systems within the DoD is challenging. Phase I is the time to plan for and begin transition and commercialization activities. The small business must convey an understanding of the preliminary transition path or paths to be established during the Phase I project. That plan should include the Technology Readiness Level (TRL) expected at the end of the Phase I. The plan should include anticipated business model and potential private sector and federal partners the company has identified to support transition and commercialization activities. In addition, key proposed milestones anticipated during Phase II such as: prototype development, laboratory and systems testing, integration, testing in operational environment, and demonstrations.

6.0 PHASE I EVALUATION CRITERIA

The offeror's attention is directed to the fact that non-Government advisors to the Government may review and provide support in proposal evaluations during source selection. Non-government advisors may have access to the offeror's proposals, may be utilized to review proposals, and may provide comments and recommendations to the Government's decision makers. These advisors will not establish final assessments of risk and will not rate or rank offeror's proposals. They are also expressly prohibited from competing for DARPA SBIR or STTR awards in the SBIR/STTR topics they review and/or provide comments on to the Government. All advisors are required to comply with procurement integrity laws and are required to sign Non-Disclosure and Rules of Conduct/Conflict of Interest statements. Non-Government technical consultants/experts will not have access to proposals that are labeled by their proposers as "Government Only."

Please note that qualified advocacy letters will count towards the proposal page limit and will be evaluated towards criterion C. Advocacy letters are not required for Phase I. Consistent with Section 3-209 of DoD 5500.7-R, Joint Ethics Regulation, which as a general rule prohibits endorsement and preferential treatment of a non-federal entity, product, service or enterprise by DoD or DoD employees in their official capacities, letters from government personnel will NOT be considered during the evaluation process.

A qualified advocacy letter is from a relevant commercial procuring organization(s) working with a DoD or other Federal entity, articulating their pull for the technology (i.e., what need the technology supports and why it is important to fund it), and possible commitment to provide additional funding and/or insert the technology in their acquisition/sustainment program. If submitted, the letter should be included as the last page of your technical upload. Advocacy letters which are faxed or e-mailed separately will NOT be considered.

Limitations on Funding
DARPA reserves the right to select and fund only those proposals considered to be of superior quality and highly relevant to the DARPA mission. As a result, DARPA may fund multiple proposals in a topic area, or it may not fund any proposals in a topic area.

7.0 PHASE II PROPOSAL

Firms will receive a notification letter after 150 days (from the contract start date) with instructions for preparing and submitting a Phase II Proposal and a deadline for submission. Visit http://www.darpa.mil/Opportunities/SBIR_STTR/SBIR_Program.aspx for more information regarding the Phase II proposal process.

11.0 CONTRACTUAL CONSIDERATIONS

Type of Funding Agreement (Phase I)

- DARPA Phase I awards will be Firm Fixed Price contracts.
- Companies that choose to collaborate with a University must highlight the research that is being performed by the University and verify that the work is FUNDAMENTAL RESEARCH.
- Companies are strongly encouraged to pursue implementing a government acceptable cost accounting system during the Phase I project to avoid delay in receiving a Phase II award. Visit www.dcaa.mil and download the "Information for Contractors" guide for more information.

Average Dollar Value of Awards (Phase I)

DARPA Phase I awards **shall not exceed $100,000 for the base effort and shall not exceed $50,000 for the option if exercised**.

11.1.s. Publication Approval (Public Release)

NSDD 189 established the national policy for controlling the flow of scientific, technical, and engineering information produced in federally funded fundamental research at colleges, universities, and laboratories. The directive defines fundamental research as follows: ''Fundamental research' means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons."

It is DARPA's goal to eliminate pre-publication review and other restrictions on fundamental research except in those exceptional cases when it is in the best interest of national security. Please visit http://www.darpa.mil/NewsEvents/Public_Release_Center/Public_Release_Center.aspx for additional information and applicable publication approval procedures. Visit http://dtsn.darpa.mil/fundamentalresearch/ to verify whether or not your award has a pre-publication review requirement.

11.7 Phase I Reports

All DARPA Phase I awardees are required to submit reports in accordance with the Contract Data Requirements List – CDRL and any applicable Contract Line Item Number (CLIN) of the Phase I contract. Reports must be provided to the individuals identified in Exhibit A of the contract.

DARPA SBIR 13.1 Topic Index

DARPA SBIR 13.1 Topic Descriptions

SB131-001 TITLE: Single Crystal Self-Assembly

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: Produce and characterize uniform barium titanate seed crystals suitable for templated grain growth. Develop and demonstrate a fabrication method to array the seeds in a matrix with orientational control of two crystal axes. Demonstrate the consolidation of the seeded matrix into a single crystal in the solid state.

DESCRIPTION: Single crystals are conventionally produced by directional solidification from the melt. They are difficult to scale up and usually require extensive machining to form near net shaped components. Significant cost reductions could be achieved by combining powder metallurgy with single crystal growth in the solid state.

Advances in templated grain growth suggest the possibility for production of true single crystals in the solid state. A key need to make this a reality is the production of uniform, faceted seed crystals that can be oriented (with 2 crystal axes) in a powder matrix and consolidated via sintering followed by secondary grain growth to form single crystals. Barium titanate (BaTiO3) is proposed as a model material because of its desirable ferroelectric and photorefractive properties. Processes with potential for chemical synthesis of seed crystals include hydrothermal, sol-gel, or other methods that allow control of the particle surface.

Success in this endeavor may be transitioned to other single crystal materials with additional functional (i.e., electronic, magnetic, acoustic or optical) properties. The BaTiO3 seed crystals should be uniform in size and shape, with a nominal diameter of 50 microns and a narrow size distribution. The growth of uniform size and shaped seed crystals will be facilitated by development of synthesis methods with fine control of nucleation and growth processes. Precipitating crystals in polymer gels for example, has been used by Henish to suppress nucleation rates (7).

Reactor design may also be important in achieving the topic goals. Plug flow reactors for example provide a uniform time – temperature profile for the product. Fluidic Self Assembly technology (8) of chips provides an example of how seed crystals might be placed in ordered arrays. Processes that use surface tension to orient the crystal may also be feasible. Pick and place methods would be challenging at small size scales. Successful development of processes to grow single crystals via self-assembly would enable growth of shaped crystals not easily made by conventional melt processes.

PHASE I: Develop a reliable and reproducible process to produce uniform sized faceted barium titanate single crystals, with a narrow size distribution centered around 50 micron diameter. Characterize the crystal facet and polar orientation of the seed crystals. Design a method to capture and array the seed crystals for characterization and for oriented placement in further fabrication steps.

PHASE II: Scale-up the process for growing seed crystals and demonstrate the reproducibility of the process by producing 3 identical batches of seed crystals. Determine a suitable process to place the seed crystals in ordered and crystalographically oriented arrays within powder preforms. They may be surrounded by structured or unstructured BaTiO3 material.

Required Phase II deliverables will include: (1) adequate seed crystals for fabrication of a large (millimeter-scale) single crystal; (2) a reproducible method to place and orient seed crystals, and (3) a model for consolidation of the array into a dense solid.

PHASE III: Commercial and military/DoD applications include lead free sonar transducers and electro-optical modulators. Barium titanate single crystals have applications as lead free ultrasonic actuators useful in medical imaging. The manufacturing technology can be extended to single crystal turbine blades, crystal textured magnets and semiconductor suitable for gamma ray scintillators.

REFERENCES:
1) PK Gallagher. Chemical Synthesis, in Engineered Materials Handbook Volume 4: Ceramics and Glasses, ASM International, 1991, pp. 52-64.

2) A Jana, S. Ram, and TK Kundu. BaTiO3 nanoparticles of orthorhombic structure following a polymer precursor. Phil. Mag., 2007, 87 (35), pp 5485-5504.

3) T Sato and T Kimura. Preparation of 111-textured BaTiO3 ceramics by templated grain growth method using novel template particles. Ceramics International, 2008, 34(4) pp. 757-760.

4) Y Chen, B Yu, J Wang, R Cochran and J Shyue. Template-based fabrication of SrTiO3 and BaTiO3 nanotubes. Inorg. Chem., 2009, 48 (2), pp 681–686.

5) DB Hovis and KT Faber. Textured microstructures in barium hexaferrite by magnetic field assisted gelcasting and templated grain growth. Scripta Met., 2000, 44, pp. 2525-2529.

6) I Soten, H Miguez, SM Yang, S Petrov, N Coombs, N Tetreault, N Matsuura, HE Ruda, and GA Ozin. Barium titanate inverted opals¾Synthesis, characterization, and optical properties. Advanced Functional Materials, 2002, 12 (1), pp. 71-77.

7) H. K. Henish, Crystal Growth in Gels, Pennsylvania University Press, Pennsylvania (1970).

8) Microfluidic self-assembly; see US Patents 5824186 and 6281038.

9) GM Whitesides and B Grzybowski. Self-assembly at all scales. Science, 2002, 295, pp. 2418-2421.

10) M Bunzendahl, P Lee-Van Schaick, JFT Conroy, CE Daith and PM Norris, Convective self-assembly of Stoeber sphere arrays. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2001, 182, pp 275-283.

KEYWORDS: Single Crystals, Barium Titanate, Templated Grain Growth, Ceramic Processing

SB131-002 TITLE: Portable Brain Recording Device & App

TECHNOLOGY AREAS: Biomedical, Human Systems

OBJECTIVE: The effort will develop a portable, inexpensive, and easy-to-use electroencephalography (EEG) device and corresponding mobile application (app) for use by nontraditional audiences. The product will provide real-time, quantitative assessments of neural activity, utilizing display and analyses platforms people already own.

DESCRIPTION: EEG technologies provide recordings of electrical brain activity with millisecond scale temporal resolution. These devices are used extensively in research and medical communities, including triaging for traumatic brain injury (TBI; Naunheim et al., 2010), because of their unparalleled temporal fidelity and non-invasive nature, using electrodes placed on the scalp. More recently EEG has been used in neuromarketing and to provide neurofeedback with brain computer interfaces to allow people to move objects or play computer games with their mind.

Despite these advantages and applications of EEG, historically the devices and analysis software are too expensive to promote use by a wide audience. Current research-grade EEG devices are also unappealing for the general population, with gel-based electrodes and cumbersome software programs, and unwieldy for military operational use, with many recording electrodes and wires. The commercial systems that are available and could potentially be used by a wider audience either remain expensive, are scientifically suspect, or are not flexible with regards to electrode number and placement.

Industry has recognized the need for a portable, easy-to-use EEG and a number of companies have developed simplified systems. Many of these devices, which cost $500 for the headset, are plagued by high artifact in recordings and do not provide the fidelity of data needed for valid research and operational use. These devices are typically comprised of one or only a handful of sensors with fixed locations on the scalp. This low number and lack of flexibility in recording locations drastically limits the ability to use these devices to collect quality recordings for research. Typically these commercially available portable EEG systems are used for biofeedback and gaming communities. Portable EEG systems that do provide research quality data are prohibitively costly for use by a wide audience, costing over $25k per EEG system.

There is a great need for inexpensive and easy to use neural recording devices. Having EEGs in every classroom in America would engage students in science and technology in a way not previously possible in the field of neuroscience. Teachers could design lesson plans in biology about the brain and sensory systems, and use hands-on demonstrations to engage students. Students could record their own brain activity and download the data to their iPad. Including EEGs in basic military first aid kits would also help with both medical diagnostics and clinical care for deployed soldiers. Portable EEGs could be used in the field, with data sent to a corresponding app on a smartphone for near-instantaneous analysis. The Department of Defense has an interest in encouraging science, technology, engineering and mathematics (STEM) pursuits, and developing a low-cost, flexible EEG device with advantages over state of the art technologies would allow many researchers to address basic and applied EEG issues in a DoD-salient fashion, ranging from building algorithms to detect incipient sleep, to diagnosing or triaging pre-clinical Post Traumatic Stress Disorder symptoms, to providing low-cost interfaces for computer training and education which modulate student feedback based on brain state.

The proposed device would provide three significant advantages over current technologies: 1) a reduced price, costing around $30 to allow widespread use by schools and average citizens, 2) easy to use sensors that could be placed in multiple locations on the head to record activity in various brain regions, and 3) the ability to download information directly to a personal tablet or mobile phone without requiring a proprietary interface or dongle.

By funding a small business with expertise in developing a portable EEG, DARPA stands to make unprecedented strides in this technology. Focusing on reducing the cost and increasing the operational ease of use for both EEG recordings and analyses will revolutionize public- and military-based access to brain science. With public-access to brain recording devices and apps, the field of cognitive neuroscience will be able to take advantage of crowd-sourcing to solve complex neuroscience problems. What challenges one laboratory of neuroscientists or even a field of scientists cannot answer, people everywhere will be able to solve collectively (Ekins and Williams 2010, Howe 2008).

PHASE I: Develop an initial concept design and model key elements for a low-cost, portable EEG system. Design a concept for an app for mobile devices that could wirelessly download EEG recordings and graphically display data. Phase I deliverables will include a technical report and brief describing the plan of approach and key technological milestones for the development of a prototype system.

PHASE II: Develop, demonstrate, and validate the concept design created in Phase I for the low-cost EEG device (~$30). Construct and demonstrate the operation of a prototype for this device in a relevant environment. In parallel to this EEG development, develop, test, and demonstrate validity of an EEG-compatible app for mobile devices. Required Phase II deliverables will include the prototype EEG sensor and compatible application, and a technical report and brief describing 1) the system design and test results for the EEG device, 2) the mobile device app, 3) and feasibility of use in future commercial and/or military applications.

PHASE III APPLICATIONS: A portable, low-cost EEG device and handheld app for analysis would aid all branches of the US military, with particular applicability to the US Army. Soldier medics with access to EEG on the battlefield would have improved diagnostic capabilities, essential to effective treatment. EEG has been shown effective as a quick triage method for TBI. EEG crowd-sourcing systems could attack multiple areas discussed above, ranging from brain-computer interfaces to driving innovative feedback regimes for digital tutor or electronic learning systems (including extant systems being acquired by the Navy and other DoD entities for operational use).

Many commercial entities would have interest in a low-cost, portable, and easy-to-use EEG. Potential marketplace applications exist in neuro-marketing, gaming, politics, and many other fields. In addition to Army medics, civilian doctors could use this device for triaging TBI patients in hospitals.

A great opportunity exists in the STEM education field as well. Placing these devices in every school would provide an invaluable resource to inspire the next generation of scientists and engineers in America and would provide an unprecedented opportunity for crowd-sourcing in the general population.

REFERENCES:

1) Ekins S and Williams AJ. 2010. Reaching out to collaborators: crowdsourcing for pharmaceutical research. Pharm Res. 27(3):393-5.

2) Howe J. 2008. Crowdsourcing: why the power of the crowd is driving the future of business, New York, Crown Publishing Group.

3) Naunheim RS, Treaster M, English J, Casner T, Chabot R. 2010. Use of brain electrical activity to quantify traumatic brain injury in the emergency department. Brain Inj. 24(11):1324-9.

KEYWORDS: Neural recordings, mobile device

SB131-003 TITLE: Automatic Detection and Patching of Vulnerabilities in Embedded Systems

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop innovative techniques to automatically detect and automatically patch vulnerabilities in networked, embedded systems.

DESCRIPTION: Embedded systems form a ubiquitous, networked, computing substrate that underlies much of modern technological society. Examples include: supervisory control and data acquisition (SCADA) systems, medical devices, computer peripherals, communication devices, and vehicles. Networking these embedded systems enables remote retrieval of diagnostic information, permits software updates, and provides access to innovative features, but it also introduces vulnerabilities to the system via remote attack.

A study by Cui and Stolfo [1] showed that there exist an extensive number of unsecured, embedded, networked devices that are trivially vulnerable to exploitation by remote attackers. Furthermore, a recent report by McAfee Labs [2] predicted that in 2012, industrial threats to SCADA systems and industrial controller systems (ICS) will mature and segment and that embedded hardware attacks will widen and deepen. The state of the practice of security for traditional IT systems is anti-virus scanning, intrusion detection systems, and a patching infrastructure. This approach does not work well in the IT space for a variety of reasons, including its focus on known vulnerabilities and the fact that security code can itself introduce new vulnerabilities. Attempts to port these approaches to embedded systems are unlikely to be any more successful because embedded systems impose additional difficulties, such as, strict resource constraints, hard real-time performance requirements, reliability over long periods of time, and the need for extensive verification and validation before patches can be installed [3].

Currently, only a small amount of research has been dedicated to developing techniques for detecting and patching vulnerabilities in embedded systems [4]. DARPA seeks to develop novel technology for automatically detecting and automatically patching vulnerabilities in networked, embedded systems. The technology should represent practical and effective techniques that can be applied to a wide-range of embedded system platforms. In addition, the techniques should be versatile such that it can be implemented on systems externally networked by various mechanisms, including, Bluetooth, Wi-Fi, radios, etc. In the defense sector, this technology will lead to more secure military systems ranging from unmanned ground, air and underwater vehicles, to weapons systems, satellites, and command and control devices. Manual techniques for detecting and patching vulnerabilities are not within the scope of this topic and should not be submitted for consideration.

PHASE I: Develop novel techniques for automatic detection and automatic patching of vulnerabilities in networked, embedded systems. Required Phase I deliverable includes a final report that details the proposed techniques, the level of vulnerability expected to be achieved by the techniques, and the anticipated amount of software development required.

PHASE II: Demonstrate that the techniques from Phase I can be practically and effectively applied to any general networked, embedded system connected by any external means, such as, Bluetooth, Wi-Fi, radios, etc. Required Phase II deliverables include all documentation and software for the techniques and a demonstration of the techniques on multiple networked, embedded system platforms.

PHASE III: It is envisioned that this technology can be applied to both defense (e.g., unmanned ground, air and underwater vehicles, weapons systems, satellites, and command and control devices) and commercial (e.g., SCADA systems, medical devices, computer peripherals, communication devices, and vehicles) sectors. Develop a commercial service or product of this technology that can be commercialized into the private sector. For example, this technology can be integrated into a larger security software product suite (i.e., McAfee, Symantec, etc.) and would represent a specialized tool that can be applied specifically on networked, embedded systems, as opposed to current security tools designed specifically for traditional IT systems.

REFERENCES:

1) A. Cui and S. Stolfo, “A Quantitative Analysis of the Insecurity of Embedded Network Devices: Results of a Wide-Area Scan”, ACSAC, pages 97-106, 2010.

2) McAfee Labs, 2012 Threats Predictions, http://www.mcafee.com/us/resources/reports/rp-threat-predictions-2012.pdf.

3) C. Ebert and C. Jones, “Embedded Software: Facts, Figures, and Software”, IEEE Computer Society, pages 42-52, April 2009.

4) A. Cui and S. Stolfo, "Defending Legacy Embedded Systems with Software Symbiotes", The 14th International Symposium on Recent Advances in Intrusion Detection (RAID), September 2011.

KEYWORDS: Vulnerabilities of Embedded Systems, Automatic Detection, and Automatic Patching

SB131-004 TITLE: Integrated Microsystems to Sense and Control Warfighter Physiology for Military Diver Operations

TECHNOLOGY AREAS: Biomedical, Sensors

OBJECTIVE: Develop an integrated microsystems platform that dynamically senses and controls warfighter physiology to enable extreme military dive operations.

DESCRIPTION: Consequences of inhaling gases at high pressure were originally encountered during undersea salvage and construction over a century ago. Empiric depth and time limits were found to reduce gas bubble formation in tissues that caused the “bends”. We continue to limit adverse physiology – now expanded to include decompression sickness (DCS), oxygen toxicity, inert gas narcosis, and high pressure nervous syndrome (HPNS) – primarily by breathing static gas mixtures at prescribed pressures and durations. Longstanding US Navy dive regulations and technologies mandate use of standard gas mixtures, rate of descent, rate of ascent, depth, and bottom time.

While dive technology has changed little in the last two decades, recent advances in applied physiology and microsystems technology could coalesce into revolutionary capability. Nitric oxide (NO) is an example of a gas that could be dynamically added to the inhaled gas mixture to improve dive operations and safety. Although trace gases such as NO were traditionally considered “poisons”, they are now known as naturally occurring biomolecules that play a critical role in cellular signaling and metabolism. Of relevance to the current topic, inhaled NO relaxes blood vessels and increases tissue perfusion with a rapid onset/offset of action. Within the Defense Advanced Research Projects Agency (DARPA) Rapid Altitude and Hypoxia Acclimatization (RAHA) program, inhaled NO was found to improve tolerance to hypoxia. In the dive environment, NO donors such as nitroglycerin also have been shown to decrease incidence of DCS. Of note, inhaled NO is Food and Drug Administration (FDA) approved for the treatment of pulmonary hypertension.

Combining the physiologic effect of inhaled gases such as NO with in vivo monitoring of pre-symptomatic risk factors such as microbubble formation could reduce the risk of adverse events such as DCS, but requires novel algorithms for dynamic control of pressure-related physiologic conditions, constant physiological feedback, and precise gas administration.

This solicitation calls for novel gas mixtures, models and algorithms that extend operational capabilities while minimizing the risk of the following:

- DCS—gas expansion injuries and bubble formation in blood and tissue caused by rapid ascent;
- oxygen toxicity—increased partial pressure of oxygen (PO2 > 1.6 ATA) resulting in seizures;
- gas narcosis—euphoria and decrement in intellectual and psychomotor performance related to the lipid solubility of the gas; and
- hypoxia—decrement in cognition and performance related to low partial pressure of oxygen. The dynamic sensing and control could include but is not limited to such gases as O2, COx, NOx, H2S, and inert gas diluent.

Additionally, this solicitation seeks to develop novel component technologies including but not limited to: chip-scale gas chromatograph / mass spectrometer (to actively and rapidly monitor inspired and expired gases/agents); capacitive micro-machined ultrasonic transducer arrays (for in vivo bubble detection and environmental monitoring); and gas/vapor control elements such as MEMS gas pumps, valves and nebulizers that could be integrated into a physiologic control system for extreme environments. Such new component technologies may also support next generation military open circuit, semi-closed circuit or close circuit rebreather systems.

The platform should enable safe operation in this representative extreme combat dive profile: (1) insertion via military free fall from 35,000 feet flight level; (2) a brief surface interval; (3) combat dive down to 200 feet sea water (FSW) for at least 120 minutes duration, surface and immediately begin a second dive of variable, increasing depth with minima at 100 FSW (for at least 10 minutes), 150 FSW (for at least 10 minutes), and 200 FSW (for at least 20 minutes) without decompression obligation; (4) brief surface interval; and (5) extraction in an unpressurized aircraft below 14,000 feet mean sea level.

PHASE I: Define the gas mixtures suitable for the representative dive profile. Explore and develop requirements for the dynamic mixed gas model and control algorithm. Develop a high level model and control algorithm, to be informed by Phase II in vivo experimentation and data collection. Select representative component microsystem technologies for proof of concept and development. Design a breadboard mixed gas platform for use in simulated dive profile(s) within a chamber. Develop the military and Occupational Safety and Health Administration (OSHA) regulatory approval plan for the component technologies and integrated device.

Phase I deliverables: A report defining (1) Opportunities and limitations of selected gases; (2) current state-of-the-art and limitations of component technologies including model/algorithm, physiologic sensors, gas sensors, and gas control components; (3) high level model and control algorithm; (4) detailed design of breadboard system; and (5) proposed animal chamber testing and regulatory approval plan.

PHASE II: Develop, demonstrate, and validate a dynamic model and control algorithm using a small animal model. Build a breadboard mixed gas system that includes the necessary control algorithm, physiologic sensors, gas sensors, and gas control components for use in chamber experiments. The breadboard system shall be demonstrated using the defined profile. At the conclusion of Phase II the performer shall provide a detailed plan for algorithm optimization, hardware miniaturization and integration into a prototype device, and transition of a man-portable prototype device into operationally relevant environments. As such, full and traceable documentation of in vivo testing that meets regulatory requirements must be provided in order to move to Phase III.

Phase II deliverables: (1) Dynamic mixed gas model and control algorithm that enables extreme combat diving with limited risk of complications; (2) breadboard system that includes the necessary algorithm, physiologic sensors, gas sensors, and gas control components; (3) prototype integrated microsystem device design; and (4) detailed regulatory approval, transition, and commercialization plan.

PHASE III: Phase III commercial application will focus on exploration and extraction of undersea oil, gas, and minerals. Improved deep water site access, operations, and safety should limit cost and environmental impact of production of natural resource necessary for US economic and military viability. Phase III military application will focus on robust military diving operations. Specific applications include expanded special operations and EOD capabilities.

REFERENCES:
1) Bennett and Elliott's physiology and medicine of diving (5th ed.). Bennett, P; Rostain, J. United States: Saunders Ltd (2003).

2) The future of diving: 100 years of Haldane and beyond. Lang, M. Brubakk, A. ed.; Washington, D.C.: Smithsonian Institution Scholarly Press, 2009. (ISBN: 9780978846053).

3) DARPA Rapid Altitude and Hypoxia Acclimatization (RAHA) and Surviving Blood Loss (SBL) programs: http://www.darpa.mil/Our_Work/DSO/Programs/Rapid_Altitude_and_Hypoxia_Acclimatization_(RAHA).aspx;

4) Inhaled NO as a therapeutic agent. Bloch KD, Ichinose F, Roberts Jr. JD, Zapol WM. Cardiovascular Research 2007. 75:339-48.

5) Exogenous nitric oxide and bubble formation in divers. Dujic Z, Palada I, Valic Z, Duplancic D, Obad A, Wisloff U, Brubakk AO. Med Sci Sports Exerc. 2006. Aug;38(8):1432-5.

6) Hydrogen sulfide and nitric oxide are mutually dependent in the regulation of angiogenesis and endothelium-dependent vasorelaxation. Coletta C, Papapetropoulos A, Erdelyi K, Olah G, Módis K, Panopoulos P, Asimakopoulou A, Gerö D, Sharina I, Martin M, Szabo C. PNAS. 2012. Jun; 109 (23): 9161–9166.

7) Assessment of extravascular lung water and cardiac function in trimix SCUBA diving. Marinovic J, Ljubkovic M, Obad A, Breskovic T, Salamunic I, Denoble PJ, Dujic Z. Med Sci Sports Exerc. 2010. Jun;42(6):1054-61.

8) Representative chip-scale gas chromatograph developed within DARPA Micro Gas Analyzer (MGA) program: http://depts.washington.edu/cpac/Activities/Meetings/Fall/2010/documents/SimonsonCPACv3.pdf.

9) Capacitive Micromachined Ultrasonic Transducers for Therapeutic Ultrasound applications. Wong SH, Kupnik M, Watkins RD, Butts-Pauly K, Khuri-Yakub BT. IEEE Transactions on Biomedical Engineering 2010. Jan;57(1):114-23.

KEYWORDS: Microsystem technology, dive physiology, modeling, dive algorithm, extreme environment, combat diving, undersea physiology, mixed gas diving, decompression sickness, oxygen toxicity, nitrogen

SB131-005 TITLE: Biodegradable Electronic Materials for Biomedical Applications

TECHNOLOGY AREAS: Materials/Processes, Biomedical

OBJECTIVE: Identify and develop a set of biodegradable materials and industry-compatible fabrication processes for demonstrating fully biodegradable, biomedical sensor/actuator systems with electronic performance comparable to SOI-based systems. Demonstrate ability to spatio-temporally control electrical function for therapeutic applications such as surgical site infection (SSI) mitigation and nerve stimulation for chronic pain relief.

DESCRIPTION: Electronically active biomedical systems that can harmlessly and controllably resorb into the body open new avenues to therapeutic applications that are currently unfeasible. Those of specific interest to DARPA and the DoD include continuous in vivo monitoring with external, wireless power and receivers (e.g. for prosthetic fit or bone fractures), appliques that combat broad-spectrum surgical site infections (SSI) without antibiotics (e.g. for wound healing or medical implants), electrical stimulation-based modalities to combat chronic pain without opioids, or electrical simulation for regenerative applications.

Furthermore, in limited resource areas such as DoD deployment locations, remote or impoverished geographic areas, or emergency response locations where clinical care is limited, biodegradable biomedical devices would enable remote patient monitoring, compliance, and treatment and would negate the need for device extraction. However, these applications are currently untenable because the materials space fails to resolve key technical challenges to implementation.

Current approaches to biodegradable, biocompatible sensor/actuator systems for medical therapeutics and monitoring provide limited utility and poor performance for two key technological reasons: 1. Demonstrations that utilize biodegradable organic/polymer-based active regions to produce the electrical function, lack the electronic performance (e.g. carrier mobility, µ, typically ~0.1-1 cm2/V-s) to be of significant utility beyond low power transistors; 2. Other examples segregate the biodegradable function to the non-electronically active components while leaving behind non-degradable elements (where biocompatibility is an issue) that require future extraction. The extraction costs related to patient care, morbidity, and mortality, and additional risks associated with surgical site infections and antibiotic-resistant strains (and their combined danger) make additional device extraction undesirable; however allowing the device to persist inflicts unnecessary burden on the patient and potential future complications.

Potential avenues to successful development of the aforementioned applications all require the identification, development, and optimization of electronic materials with performance amenable to simple low power systems with onboard processing (e.g. semiconductor active regions with electron mobility, µn, ~102 cm2/V-s). Critically, all materials under development must be biocompatible and bioresorbable. Devices developed under this SBIR must demonstrate stable functionality over medically-relevant timescales (e.g. 15 days for an SSI treatment applique) and controllable bioresorption over medically-appropriate timescales (e.g. hours to weeks, depending on the material constituents). Devices developed must operate with electronic performance applicable to the purported treatment (e.g. blood pH monitoring with data transfer to external receiver at 10 minute intervals).

This topic is focused on the development of a class of biodegradable materials capable of electronic functionality comparable to traditional electronics used in low power, low cost systems. The biocompatible materials used in these systems should be optimized for functionality, performance, and tunable bioresorption timescales. Proposers should develop the materials, device designs, and manufacturing approaches. Mechanisms for power and data extraction should be described, as well as a plan for developing a fabrication process compatible with the good manufacturing practice (GMP) platform. Although the (ultimately) necessary animal model testing is not specifically funded under this solicitation, proposers should also develop and present a regulatory approval plan for successful materials classes.

PHASE I: Demonstrate through analysis and proof-of-concept experiments the feasibility of a fully biodegradable, biocompatible electronic sensor and actuator technology for a DoD-relevant biomedical application (as discussed above).

The solution should provide not only functionality in this application context, but with a set of components that are sufficiently general in their operation that they can be re-purposed for other related applications in biomedical electronics. The deliverable will be a paper study with detailed material and device analysis, together with experiments to illustrate high performance capabilities (i.e. comparable to SOI-based systems) in the key components. Mechanisms for power and data extraction should be described. Additionally, the study should include an overview and analysis of a strategy for scalable and industry-compatible fabrication processes for device production. The Technology Readiness Level (TRL) at the end of Phase I should be between 3 and 4.

PHASE II: Develop, test, and demonstrate a set of biodegradable, biocompatible materials that exhibit controllable degradation rates and electronic functionality comparable to traditional electronics used in low power, low cost devices. Construct and demonstrate the operation of an integrated prototype device capable of achieving the objective goals as described above. Demonstrate stable functionality over medically-relevant timescales (e.g. 15 days for an SSI treatment applique) and controllable bioresorption over medically-safe timescales (e.g. days to months, depending on the application). Devices developed must demonstrate electronic performance applicable to the purported treatment, along with mechanisms for onboard power, processing, and data transmission. Assess the properties of the electronics and the actuators, with quantitative comparison to computational models.

Deliverables of a prototype device and valid test data appropriate for a commercial production path are expected, as well as a demonstration of functionality in vitro. Experiments should be conducted using biospecimens and/or models appropriate for the application. Provide a detailed plan of the animal model experiments to be completed during Phase III (e.g. adsorption, distribution, metabolism, and excretion of the resorbed components, toxicity) required for regulatory approval. Establish roadmaps to commercial products, including manufacturing and regulatory considerations. The Technology Readiness Level (TRL) at the end of Phase II should be 5.

PHASE III: The technology to be developed is applicable to numerous biomedical devices for the DoD and military: enhanced wound healing and monitoring (including prosthetic fit and bone fractures), appliques that combat broad-spectrum surgical site infections (SSI) without antibiotics for wound healing or medical implants, electrical stimulation-based modalities to combat chronic pain without opioids, and electrical stimulation for regenerative applications.

Potential transition customers include Military Health System – Defense Medical Research and Development Program (MHS DMRDP), United States Army Institute of Surgical Research (USAISR), Armed Forces Institute of Regenerative Medicine (AFIRM), Military Infectious Diseases Research Program (MIDRP), and Defense Threat Reduction Agency (DTRA). The technology to be developed is applicable to biomedical devices and active scaffolds for therapeutic treatment applications as well as monitoring, diagnosis and performance measurements. There is a significant commercial market for biodegradable, medical devices and active scaffolds, particularly those currently involved in the development of technologies capable of enhancing and monitoring wound and bone fracture healing, pain relief without opioids, drug delivery, performance monitoring, and the continuous monitoring of glucose and other metabolites. The developed technology would allow improvement of existing medical devices and expansion of devices and modalities for therapeutic treatment and monitoring of additional health conditions.

REFERENCES:
1) A microfabricated wireless RF pressure sensor made completely of biodegradable materials, Solid-State Sensors, Actuators, and Microsystems Workshop, Hilton Head Island, South Carolina, June 3-7, 2012.

2) Dissolvable films of silk fibroin for ultrathin conformal bio-integrated electronics, Nature Materials 9, 511–517 (2010).

3) Biomaterials-based organic electronic devices, Polymer International 59, 563-267 (2010).

4) Manufacturing and commercialization issues in organic electronics, Journal of Materials Research 19, 1974-1989 (2004).

5) Organic thin film transistors fabricated on resorbable biomaterial substrates, Advanced Materials 22, 651-655 (2010).

6) Silicon electronics on silk as a path to bioresorbable, implantable devices, Applied Physics Letters 95, 133701 (2009).

7) Biodegradable electronics, A desirable solution, The Economist, http://www.economist.com/node/16837947, 17 August 2010.8) Brief electrical stimulation promotes the speed and accuracy of motor axonal regeneration, The Journal of Neuroscience 20, 2602-2608 (2000).

KEYWORDS: biodegradable, bioresorbable, biomedical device, wound healing, regenerative, electronics, electrical stimulation, drug delivery, biosensor, continuous in vivo monitoring, chronic pain management, antibiotic resistance

SB131-006 TITLE: <u>High Spectrum Efficiency Technologies</u>

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

OBJECTIVE: Develop innovative technologies, tools and related infrastructure that can significantly advance spectrum efficiency of wireless communications networks over current SISO QPSK TDMA technology for defense communication applications and platforms.

DESCRIPTION: Techniques and tools are sought that change spectrum efficiency from the typical principles of one waveform on one frequency at one time within a large communication interference footprint, to the ability of large numbers of communication networks to simultaneously operate in the same amount of frequency in the same area.

Spectrum efficiency is measured as bits/s/hz or alternatively as bits/s/hz/sqKm for all nodes of a network. This effort seeks to find economical and practical means to increase efficiency metrics by significant factors relative to current SISO QPSK rate ½ TDMA system examples. Particular attention should be paid to innovative methods to use the same spectrum with other heterogeneous legacy systems while minimizing cross network interference.

Many new technologies have been proposed at every layer of communication network protocol that can have important impact on spectrum efficiency.

- Proposed techniques at the physical layer include MIMO, Collaborative MIMO, MUD, Polarimetrics, DSA, OSA, Smart Antennas, Interference Alignment and overlay/underlay [1-8]. Header compression, adaptive scheduling, adaptive FEC, adaptive power control, and prioritized queuing are common additional efficiency considerations [9-10].
- Techniques have also been proposed to enhance efficiency of modulation, MAC, Link, network and application layers.
- Awareness techniques such as local capacity analysis have been proposed enabling optimization for current spectrum activity and network traffic requirements.
- Database structures and other tools have also been proposed as supporting infrastructure to enhance spectrum efficiency, including: trunking, pooling, and radio environment maps. In addition, circuit techniques have been proposed to enhance linearity and dynamic range to enable previously impractical methods for simultaneous transmission and reception (STAR) [11].

The focus of this SBIR topic is to create novel techniques and combinations of techniques leading to significantly higher systems levels of spectrum efficiency than current defense communication systems are able to achieve. Design adaptively should locally optimize current spectrum activity and traffic load conditions. It is desirable that system designs consider cost effectiveness, network performance, and practical deployment for various platforms.

Deployment platforms of interest range in scale, power and performance over the range of ships, aircraft, vehicles, robots, soldiers, and sensors. Performers must clearly demonstrate the achievable level of spectrum efficiency of their completed architecture with real world implementation considerations of channel impairments, platform motion, interference sources, non-linearity of circuit elements, antenna properties, dense deployment fields of radio networks, and variation in traffic load, resulting in useful communication networks.

PHASE I: Study, simulate, analyze and validate proposed performance levels. Results of the Phase 1 study must be quantitative for all layers of the integrated communication network protocols, referencing a standard communication network as a baseline performance of spectrum efficiency, showing system level spectrum efficiency improvement factors (TRL3-4).

PHASE II: Develop and demonstrate essential elements of the proposed architecture to an integrated system level network capable of demonstrating achieved network spectrum efficiency adapting to current spectrum and network traffic. This phase has a target Transition Readiness Level (TRL) of 5 while demonstrating the potential of progressing to TRL 6 during a possible Phase III.

PHASE III: Commercial telecommunication, public safety, and broadcast systems can all benefit from enhanced spectrum efficiency techniques by reducing cost of spectrum access to maintain the grade of service for their business. This phase should support a means to accomplish transition to production ready deployment level for defense communication systems.

REFERENCES:
1) Chen, B, Gans, M., "MIMO communications in ad hoc networks", IEEE Trans Signal Processing, July 2006.

2) Yoon, Y.C., Kohno, R., "Optimum multi-user detection in ultra-wideband (UWB) multiple-access communication systems", IEEE Intnl Conf. on Communications, 2002.

3) Pratt, T., Tapse, H., Fette, B., Baxley, R., Walkenhorst, B., Acosta-Marum, G., "Polarization-based zero forcing suppression with multiple degrees of freedom", IEEE Military Communications Conference – 2011.

4) Marshall, P., "Dynamic Spectrum Access as a Mechanism for. Transition to Interference Tolerant Systems", IEEE Symposium on New Frontiers in Dynamic Spectrum", 6-9 April 2010.

5) Zhao, Q., "Decentralized cognitive MAC for Opportunistic Spectrum Access in ad hoc networks: A POMDP framework", IEEE J on Selected Areas in Comm, April 2007.

6) Godara, L.C., Smart Antennas, CRC Press, 2004.

7) Peters, S.W., Heath, R.W., "Interference alignment via alternating minimization", IEEE Intnl Conf. on ASSP, 2009.

8) Chakravarthy, V.D., Wu, Z., Shaw, A., Temple, M.A., Kannan, R., Garber, F., "A general overlay / underlay analytic expression representing cognitive radio waveform", IEEE Intnl Waveform diversity and Design Conf., 2007.

9) Hoang, A.T., Liang,Y.C., "Adaptive Scheduling of Spectrum Sensing Periods in Cognitive Radio Networks", IEEE Globecom Nov 2007.

10) Youping Zhao, Jeffrey H. Reed, Shiwen Mao, Kyung K. Bae, "Overhead Analysis for Radio Environment Map enabled Cognitive Radio Networks", IEEE Workshop on Networking technologies for Software Defined Radio Networks, Sept 2006.

11) Bliss, D., Parker, P.A., Margetts, A.R., "Simultaneous Transmission and Reception for Improved Wireless Network Performance", IEEE Workshop on Statistical Signal Processing, 2007.

KEYWORDS: Spectrum Efficiency, Spectrum Awareness, Radio Environment Map, Software Defined Radio, Cognitive Radio, MIMO, MUD, Polarimetrics, DSA, Smart Antennas, Interference Alignment, STAR

SB131-007 TITLE: Remote Sensing for Electric and Gravity Fields

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Demonstrate the technology to remotely measure electric and gravity/gravity gradiometry fields.

DESCRIPTION: Electromagnetic and gravity intelligence, surveillance and reconnaissance (ISR) signatures are useful for revealing and characterizing adversaries' operations but these signatures decay rapidly with distance. Electric field signatures are from electrical power generators and power distribution systems. Gravity signatures are from the presence or absence of mass (in the case of an underground tunnel or facility).

Current electric field and gravity field measurement methods require close-access sensor emplacement or low-flying airborne platforms. These are operationally unsuitable because of their difficult access requirements and low coverage rates.

The goal of this effort is to replace those traditional point sensing technologies – requiring sampling near a facility and providing limited spatial extent – with remote sensing methods that decouple the sensor hardware from the measurement point and enable operationally attractive stand-offs and fast search rates. Such a system would operate from an aerial system, be able to scan from a distance of 10 kilometers, and have sufficient sensitivity to detect the operation of generator, the operational status of a power line (on/off), and the presence of an underground facility.

DARPA is not interested in improved point sensors where the field measurement point and the sensor hardware are at the same location, tomographic based solutions whereby a remote field is calculated from an array of local point measurements, or clutter rejection techniques to improve local measurements of remote fields.

Science and technologies may exist to achieve this goal. The commercial Electrical Single Particle Aerodynamic Relaxation Time (E-SPART) analyzer measures the secondary effect of a particle deflection in an AC electric field to determine the particle size and charge. The Stark effect perturbs emissions from atomic and molecular species in the presence of an electric field. Particles motion is influenced in the presence of a gravitational field.

PHASE I: Propose a system that can achieve the measurement of an electric or gravity field at a distance of 10 kilometers. Demonstrate the sensitivity that the system could achieve through analysis. Experimentally demonstrate a key technology needed to achieve the realization of the system.

PHASE II: Experimentally demonstrate the system at increasing distances and level of sensitivity. Ideally, achieve a standoff of 10 kilometers against the target sets identified above. Propose an operational configuration of the system to meet the requirements for an airborne system which is able to rapidly scan a large area.

PHASE III: Potential benefit to the military/DoD; provides a capability to locate hidden underground facilities by detecting their electric and gravity signatures. Underground facilities are often concealed to prevent visual observation, but electric and gravity signatures are difficult to obscure. Remote detection of these signatures enables detection of facilities in denied access areas.

Potential commercial benefit: Provides a capability to rapidly survey powerlines and power grids to determine breaks in power service. This is especially important after natural disasters when extensive power outages require expeditious location of broken powerlines to facilitate restoration of power service.

REFERENCES:

1) AC Stark Effect, http://budker.berkeley.edu/Physics208/beals_stark.pdf[2] Gravitational settling, http://www.epa.gov/apti/bces/module3/collect/collect.h

KEYWORDS: Remote sensing, electric fields, gravity fields

SB131-008 TITLE: Fractionated Picosats

TECHNOLOGY AREAS: Sensors, Space Platforms

OBJECTIVE: Develop and demonstrate a fractionated picosat (100 g - 1 kg) platform capable of participating in an existing System F6 fractionated satellite cluster and leveraging cluster resources to command, manage, package, and deliver Earth imagery data to the ground.

DESCRIPTION: Picosatellites (100 g - 1 kg) have been considered as a responsive and low-cost spacecraft platform; however, their utility is limited. The usefulness of picosats may be dramatically increased if they are able to coordinate with each other and participate in a System F6 satellite cluster. Such coordination would enable resources such as communication, computation, and navigation to be shared, minimizing the component complexity of any single spacecraft. Further, given the availability of an existing cluster, the marginal cost and complexity of space missions that traditionally require a conventional spacecraft (e.g., imager payloads) can be reduced to a level that is readily accommodated by a picosat.

DARPA's System F6 program plans to launch an on-orbit testbed in 2015 to demonstrate the key enabling technologies of fractionation. The program will provide the enabling standards, software, and four satellite platforms to host shared resources that may be leveraged by additional space missions. These resources include 1) a 24/7 persistent communication link between the cluster and any Internet-connected node on the ground, 2) a high-speed space-to-ground downlink, 3) a high-speed computing element, and 4) high-capacity memory storage devices.

The intent of this SBIR is development of innovative picosats capable of hosting an Earth-imaging payload and leveraging the F6 demonstration cluster and architecture to command, manage, package, and deliver Earth imagery data to the ground. The picosat should be capable of communicating with the demonstration cluster and participating in cluster flight navigation. All standards and software necessary to interface with the on-orbit cluster will be provided by DARPA. This includes the Layer 1 and 2 standards and software for inter-module communications (either 802.11g or Ka-Band TDMA), an application development kit needed to develop the picosat mission payload application that is executed on the cluster, and the cluster flight behaviors, algorithms, and reference implementation software. (The picosat platform should be capable of exchanging cluster flight navigation data, but is not required to participate in station-keeping and scatter/re-gather maneuvers).

The picosat should maximize mission utility while minimizing size, weight, and power requirements by substituting components, subsystems, and functions traditionally needed to support a spacecraft mission payload (e.g., command and data handling, attitude control, telemetry). These capabilities should be delivered by leveraging resources in the cluster and managed through a mission payload application on the cluster. The picosat should deliver at least one image of the Earth with recognizable features (e.g., coastlines) within the expected 6-month duration of the mission. No ground station support will be provided – solutions should utilize the space-to-ground links and computational resources to process and deliver the image to a specified Internet-connected computing node on the ground. Space access will be provided, but as a variety of rideshare opportunities are still being considered, the exact orbit and launch configuration are not currently available. Altitude is expected to be between 300 and 1500 km.

PHASE I: Develop a conceptual design of a fractionated Earth-imaging picosat. Phase 1 deliverables include:

- Preliminary Design Review with documentation of all design decisions, performance analyses, trade studies, schematics, size, weight, and power estimates, interface specifications, software architecture
- Software development plan
- Verification and validation plan
- Preliminary CONOPS - Description of the operational concept including how the picosat will interface with the System F6 on-orbit demonstration cluster, and how the Earth-imaging mission will be conducted

PHASE II: In Phase II, the SBIR performer will develop, demonstrate, and validate a prototype picosat and associated ground support systems and procedures. Phase II deliverables include:

- Critical Design Review with detailed documentation of the final design highlighting all changes since the Preliminary Design Review; identification of major components in the flight system including hardware components, software functions, verification and validation plans, ground support, and operational procedures
- Updated CONOPS
- Demonstration of all functional objectives on a prototype breadboard and associated software in simulated but representative orbital configurations

PHASE III: In Phase III, the SBIR performer will develop, demonstrate, and validate a flight-ready picosat and associated ground support systems and procedures. The Phase III product should fulfill Transition Readiness Level 6 (TRL6) objectives. Phase III deliverables include:

- Flight Readiness Review with detailed documentation of the final design, flight qualification test results, and end-to-end system interfaces and procedures demonstrating system readiness for launch and on-orbit operation
- Updated and final CONOPS

- Demonstration of all functional objectives on a flight-ready picosat in simulated but representative orbital configurations

Fractionated picosats are expected to have a number of relevant scientific, military, and commercial applications including space environment monitoring, space and Earth imaging, communications, and surveillance.

Inexpensive fractionated picosats will provide scientific and commercial stakeholders with enhanced system adaptability and survivability, while shortening development timelines and reducing the barrier-to-entry for participation in the space industry.

These picosats are expected to further extend the applicability of spacecraft fractionation, enabling development of enhanced cluster components, resources, and applications.

REFERENCES:
1) Hinkley, D. and Janson, S., "Building Miniature Spacecraft at The Aerospace Corporation," Crosslink, Summer 2009, http://www.aerospace.org/wp-content/uploads/crosslink/V10N1.pdf.

2) "Picosat." Wikipedia: The Free Encyclopedia. Wikimedia Foundation, Inc. 22 July 2004. Web. 18 June. 2012. http://en.wikipedia.org/wiki/PicoSat.

KEYWORDS: Picosat, Cubesat, FemtoSat, System F6, Payload, Earth-Imager

SB131-009 TITLE: Satellite Hypervisor

TECHNOLOGY AREAS: Information Systems, Space Platforms

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 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a space qualified hypervisor to support the virtualization of satellite payloads.

DESCRIPTION: Defense and Intelligence community payload development for on-board processing has been traditionally hardware based. Hardware payloads, even reprogrammable solutions, tend to limit the utility of the space vehicle and require increased algorithm development effort, since hardware-related programming is required in order to benefit from the available processing speed. New mission demands and changes in spacecraft bus and sensor technologies drive up space acquisition costs and lengthen space system acquisition times.

Virtualized payloads have the potential to increase the beneficial mission utility and life of space platforms while decreasing acquisition time and cost. In addition, a space qualified hypervisor or virtual machine monitor (VMM) has the potential to reduce the cost-to-entry barrier to space thereby expanding the space industrial base while providing an environment for commercially developed plug-and-play applications.

The goal is to develop a space qualified hypervisor which will support the virtualization of satellite payloads. This will increase the capability and flexibility of a new category of spacecraft, allowing them to adapt their mission and processing to meet the ever evolving needs of the Defense and Intelligence community.

PHASE I: Conduct feasibility studies, technical analysis and simulation, and conduct small scale proof of concept demonstrations of the proposed satellite hypervisor. Develop an initial conceptual approach to using a hypervisor to host a satellite's virtualized mission payload(s). This would include quantified system estimates for mass, volume, power requirements, and duty cycles. Deliverables should include monthly status reports, feasibility demonstration reports and any hardware or software produced.

PHASE II: Implement technology assessed in Phase I effort. The Phase II effort should include initial space qualified hypervisor designs, code, and breadboard validation in a laboratory environment. Initial technical feasibility shall be demonstrated, including a demonstration of hosting virtual payloads. Demonstration should include evidence that the system, as designed, could provide adequate processing capability to allow for hyperspectral data acquisition, polarimetric synthetic aperture radar (POLSAR) imaging or similar data intensive mission (currently limited by the economics of data download to ground receiving station or accomplished through imposing severe restrictions in terms of capture duration, resolution, and swath width). Deliverables should include quarterly status reports, design documentation and any software or hardware produced.

PHASE III: There is a perceived potential for commercialization of this technology. The primary customer for the proposed technology will initially be the Department of Defense, but there could also be other applications in the areas of commercial satellite communications. Also, commercial versions of the hypervisor could be produced for civilian and scientific applications. Commercial satellite manufacturers could incorporate them into a variety of commercial satellite systems for sale to various interested customers. Commercial companies could also provide competitively priced space hypervisor hosted applications, communications or remote sensing services to paying customers, including the national security community.

The contractor shall finalize technology development of the proposed space hypervisor and begin commercialization of the product. In addition to military communications or intelligence, surveillance and reconnaissance (ISR) missions, commercial civilian applications for a space qualified hypervisor could include space-based satellite communications. Phase III should solidly validate the notion of a space qualified hypervisor with a low level of technological risk. The goal for full commercialization should ideally be Technology Readiness Level 9, with the actual system proven through successful mission operations. Specifically, Phase III should ultimately produce a hypervisor suitable for hosting space system payloads. The contractor must also consider manufacturing processes in accordance with the President’s Executive Order on “Encouraging Innovation in Manufacturing” to insure that the innovations developed under this SBIR can be readily manufactured and packaged for transportation and deployment.

During Phase III, this capability could conceivably transition or expand to the appropriate division of Air Force Space Command upon full rate production and deployment.

REFERENCES:
1) MCGLOUGHIN, I., BRENTSCHNIDER, T. 2010. Reliability Through Redundant Parallelism for Micro-Satellite Computing in ACM Transactions on Embedded Computing Systems, Vol. 9, No. 3, Article 26, Publication date: February 2010.

2) S. Peir´o, A. Crespo, I. Ripoll, M. Masmano, Partitioned Embedded Architecture based on Hypervisor: the XtratuM approach, Eighth European Dependable Computing Conference, EDCC-8 2010, Valencia, Spain, 28-30 April 2010. IEEE Computer Society 2010, ISBN 978-0-7695-4007-8.

3) McLoughlin, I.V.; "Virtualized Development and Testing of Embedded Computing Clusters," Networking and Computing (ICNC), 2011 Second International Conference on, pp.17-26, Nov. 30 2011-Dec. 2 2011.

4) J. Windsor and K. Hjortnaes. Time and space partitioning in spacecraft avionics. In IEEE Conference on Space Mission Challenges for Information Technology, July 19-23. Pasadena (USA) 2009.

5) Cutler, J.W.; Fox, A.; Bhasin, K.; "Applying the lessons of Internet services to space systems," Aerospace Conference Proceedings, 2002. IEEE, vol. 7, pp. 7-3287- 7-3295.

KEYWORDS: Hypervisor, virtualization, space, satellite, virtual machine monitor, VMM