DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)
13.A Small Business Technology Transfer (STTR) Program
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 Technology Transfer (STTR) Program rests with the Small Business Programs Office.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Attention: DIRO/SBPO
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(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 STTR 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 STTR Policy Directive issued by the Small Business Administration.

3.0 DEFINITIONS

3.4 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.

3.5 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.

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

A Phase I Cost Volume ($100,000 maximum) must be submitted in detail online via the DoD SBIR/STTR submission system. 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 STTR 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 STTR 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 STTR 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.

5.5 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. 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.
____3. The base effort does not exceed $100,000.
____4. The technical volume does not exceed twenty (20) pages. Any page beyond 20 will be redacted prior to evaluations.
____5. 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, 27 March 2013.

____6. 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.

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.

10.0 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**.

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.

10.7 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 STTR 13.A Topic Index

DARPA STTR 13.A Topic Descriptions

ST13A-001 TITLE: Functional Imaging to Develop Outstanding Service-Dogs (FIDOS)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: This effort will capitalize on first-of-its-kind neural imaging feasibility work; demonstrating functional brain activation in unrestrained dogs in response to handler cues. The objective of this effort is two-fold; first, to optimize the selection of ideal service dogs, both in operational military and therapy environments, and second, to use real-time neural feedback to optimize canine training, shortening training duration, reducing costs, and increasing learned responses.

DESCRIPTION: Military working dogs are used in a variety of operations, including bomb detection, search and rescue, and drug interdiction. Service dogs are also utilized in clinical settings, as therapy dogs to mitigate symptoms of Post-Traumatic Stress Disorder (PTSD) and Traumatic Brain Injury (TBI) in returning service members. Certain dog breeds, ideal for this work, are rare (a limiting resource) and variability in dog training and performance limits their effectiveness in operational environments. Better selection and screening of service dogs would ensure that the best dogs, with optimal motivation and trainability are selected for service. Current training regimens are driven by classic behaviorism, involving simple reward/punishment conditioning. They are time-intensive and costly, costing more than $20,000 per dog-human pair (in clinical animal-human work pairs). Therefore, this program will address these two problems by 1) providing quantitative means for selecting service dogs for training and 2) providing quantifiable evidence-based methods for optimal canine training techniques.

Canine training paradigms require a cognitive revolution to take advantage of recent advances in brain imaging. A first-ever functional Magnetic Resonance Imaging (fMRI) study in awake, unrestrained dogs (Berns et al., 2012) confirmed that the dog brain reward system in the caudate nucleus reacts to a primed reward hand signal. These results provide a first-ever window into the brain of man’s best friend, providing a glimpse of how dogs functionally process human trainer signals and to what extent different brain networks are activated by these signals.

In both the operational and clinical settings, better canine selection and screening methods would reduce training time and costs and result in more effective service dogs. Now, with this state-of-the-art canine neuroimaging tool in hand, potential high-value service dogs could be screened based on their neural activation to specific handler training cues. The hypothesis is that dogs with greater activation in the caudate nucleus in response to handler cues will be faster and easier to train. These experiments would result in better use of scarce canine resources (e.g., the rare Belgian Malinois breed) and better service dogs.

The mechanisms of canine TBI and PTSD therapy effectiveness are not well understood, and training and implementation methods are ripe for improvement. One hypothesis is that effective therapy dogs are better able to sense their owner’s mental state and emotions. Some research suggests that dogs may, in fact, possess robust “theory of mind” (the ability to attribute mental states such as beliefs, desires and attitudes, to another person). For example, dogs are known to follow human’s gaze and pointing (Kirchhofer et al., 2012) and show contagious yawning, more so with their owners than with strangers (Silva et al., 2012). This method of canine neuroimaging could be used to identify ‘brain hyper-social’ dogs ideally suited to TBI or PTSD therapy work. Correlating the dog's brain activity within the caudate nucleus with neurophysiological markers of handler stress and anxiety could provide a screening tool for dogs ideally suited to therapy work.

In addition to optimizing the selection of ideal service dogs, a canine neuroimaging tool could pave the way for revolutionized service dog training paradigms. The identification of caudate activation by Berns et al. (2012) demonstrates that canine-imaging studies could quantify the relationship between handler signal and intrinsic reward without reliance on a behavioral proxy. Currently, handlers must reward approximations of a desired behavior to teach a dog a desired task. However, associations can be made prior to behavioral manifestation. Monitoring brain activation in real-time could allow trainers to reward proper brain activation patterns indicative of associative learning. These methods could be used to quickly measure how effective a given training technique is and provide quantitative, evidence-based rationale for selecting superior training methods. They would also increase the speed and efficacy of canine training, useful in both operational and therapy domains.

Advances in understanding the influence of dog training techniques on the canine brain 1) will enhance selection of highly-trainable work dogs and 2) will enable faster, cheaper, and more effective training of military work and therapy dogs. Overall, this project represents a radical new method of quantitatively measuring cross-species communication, coordination, and therapeutics.

PHASE I: Develop a reproducible training method for imaging canines while awake and unrestrained. Previous work involved training only two dogs and was trial-and-error based (Berns et al., 2012). A more stream-lined method will be needed for quickly and reliably training service dogs. The small business's expertise in dog training will be particularly crucial for this objective.

In Phase I, animal use protocols will be developed and approved, per normal procedures. Initial work in this field has validated that animals can be trained for safe and humane scanning in the fMRI (Berns et al, 2012). Similar methods employed in this study will be needed in future dog imaging studies. The large size of some training dogs presents a technical challenge for positioning in the scanner. Equipment modifications will be completed in Phase I to ensure proper access to the scanner and canine comfort in the experiments. Phase I deliverables will include 1) a technical report and brief describing the training method, and 2) a set of experiments demonstrating proof of concept for scanning reward-related brain activity in the service dogs.

PHASE II: Finalize and validate a training method for training large dogs to undergo fMRI scanning while awake and unrestrained. Establish performance parameters through experiments that produce reliable brain images of responses to trainers' hand cues, which can be used to test ideal military dog training methods. Develop, demonstrate, and validate protocols that combine canine imaging and simultaneous human neurophysiological measures in order to examine dog-human interactions. Apply these protocols to study what dogs are best suited for use in therapeutic situations and quantify the relationship between this suitability and clinical outcomes. Required Phase II deliverables will include a technical report and brief describing the training methods and findings from canine brain scans, as well as feasibility of use in future commercial and/or military applications.

PHASE III: Law enforcement agencies train and use work dogs for many of the same operations as the military; therefore, transition to this customer would be seamless. Improved canine training techniques could also be used by commercial dog training organizations, for behavior improvement or therapy applications. Training techniques developed in Phase I and II will substantially reduce canine training time and costs by selecting ideal dogs and optimizing training techniques. These techniques will be transitioned to the US Air Force, which runs the DoD Military Working Dog Program from Lackland AF Base, San Antonio, TX (341st Training Squadron).

Advances from this program could also be transitioned to the Veterans Administration, which is running a clinical trial on the impact of therapy dogs on the lives of veterans diagnosed with PTSD. Understanding the mechanism and communication between canine and human will facilitate therapy dog support for veterans with PTSD.

REFERENCES:
1) Berns GS, Brooks AM, Spivak M. 2012. Functional MRI in awake unrestrained dogs. PLoS One. 2012;7(5):e38027. Epub 2012 May 11.

2) Kirchhofer KC, Zimmermann F, Kaminski J, Tomasello M. 2012. Dogs (Canis familiaris), but not chimpanzees (Pan troglodytes), understand imperative pointing. PLoS One. 7(2):e30913.

3) Silva K, Bessa J, de Sousa L. 2012. Auditory contagious yawning in domestic dogs (Canis familiaris): first evidence for social modulation. Anim Cogn. Jul;15(4):721-4.

KEYWORDS: Enhanced training, improved therapy, PTSD, stress, neural correlates, brain imaging, cross-species communication

ST13A-002 TITLE: High-bandwidth, Low-sensitivity Optomechanical MEMS Accelerometers

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Develop a chip-integrated optomechanical micro-electromechanical systems (MEMS) accelerometer with 100 ng/Hz^1/2 sensitivity and 10 kHz bandwidth using high finesse optics to readout and dynamically tune sensor parameters.

DESCRIPTION: Inertial navigation systems (INS) are a critical asset to the DoD in environments where GPS is either denied or unavailable. At the heart of these systems are precision acceleration and rotation sensors. Recently, MEMS-based accelerometers have found widespread use in INS owing to their small size and ease of fabrication. However they still lack the sensitivity and bandwidth required for accurate long-distance navigation. Typically, MEMS accelerometers use capacitive measurement; their sensitivities are limited by thermal-electronic noise in the readout circuitry [1]. Optical interferometric methods eliminate electronic noise and can approach the thermal-mechanical limit [2], [3]. This thermal-mechanical noise imposes a fundamental trade-off between the sensitivity (ath) and bandwidth (BW) of the accelerometer: ath proportional to (BW/mQ)^1/2, where m is the mechanical resonator mass and Q is its quality factor. Therefore, to achieve a high sensitivity for a given bandwidth, the product mQ needs to be maximized. Furthermore, for high bandwidth devices, a high resolution displacement (x) measurement is required (x proportional to BW^-2), thus imposing requirements on the finesse (F) and input power (P) of the optical readout cavity (x proportional to (F^-1P^-1/2)), which is ultimately limited by laser shot noise. For example, to achieve a sensitivity of a few ng/Hz^1/2 at a bandwidth of 10 kHz, one would require mQ > 1 kg and F > 1000. Such a sensitivity and bandwidth combination has not been achieved in a commercial device and would reduce the INS error, allowing longer-duration navigation in the absence of GPS.

Recently, accelerometers based on optomechanical devices have been developed, which exhibit a sensitivity of a few ng/Hz^1/2 with a bandwidth greater than 10kHz, in a compact form-factor [4], [5]. Optomechanical devices are strongly coupled optical and mechanical systems, in which a high finesse optical cavity is used to both measure and manipulate high-quality MEMs. Such devices have enabled optical radiation-pressure cooling of MEMs to their quantum ground state [6], eliminating thermal noise and enhancing the achievable bandwidth by broadening the mechanical resonance without loss of sensitivity. Furthermore, the cavity-enhanced optical field enables displacement measurement at the standard quantum limit [7], an important fundamental limit for acceleration sensing. Finally, utilizing the high circulating power achievable in a high finesse cavity, one can dynamically control the bandwidth of the MEMS accelerometer via the optical spring effect [8], thus enabling unprecedented in-situ control of accelerometer performance.

While optomechanical devices have demonstrated exciting results in the laboratory, significant development is necessary to construct a robust packaged device that incorporates the laser, the optomechanical device, and optical readout circuitry.

PHASE I: Design a robust, packaged MEMS accelerometer with highsensitivity optical readout approaching the standard quantum limit for displacement measurement. Such a system should exhibit high opticalmechanical coupling such that a pump laser can manipulate MEMS parameters such as resonance frequency and damping rate. The chosen work should be compatible with an accelerometer with less than100 ng/Hz^1/2 sensitivity and greater than a 10 kHz bandwidth. Exhibit the feasibility of the approach through a laboratory demonstration. Phase I deliverables will include a design review including expected device performance and a report presenting the plans for Phase II. Experimental data demonstrating feasibility of the proposed device is favorable.

PHASE II: Fabricate and test a prototype device demonstrating the device performance outlined in Phase I. The Transition Readiness Level to be reached is 5: Component and/or bread-board validation in relevant environment.

PHASE III: Once developed, compact, integrated optomechanical accelerometers with high-sensitivity and high-bandwidth would greatly improve military inertial navigation systems, requiring less frequent error correction and updates from GPS. Innovations in Phases I and II will enable such devices to transition out of the laboratory and into fieldable devices. MEMS accelerometers find widespread use in civilian products such as cellphones, seismic detection (geo-physical and oil exploration), automobiles and gravitational wave detection.

REFERENCES:

1) G. Krishnan, C. Kshiragar, G. K. Ananthasuresh, and N. Bhat, "Micromachined high resolution accelerometers," Journal of the Indian Institute of Science, vol. 87, no. 3, Jul. 2007.

2) M. A. Perez and A. M. Shkel, "Design and Demonstration of a Bulk Micromachined Fabry–Perot mico-g-Resolution Accelerometer," IEEE Sensors Journal, vol. 7, no. 12, pp. 1653-1662, Dec. 2007.

3) K. Zandi, J. A. Bandlanger, and Y.-A. Peter, "Design and Demonstration of an In-Plane Silicon-on-Insulator Optical MEMS Fabry Perot-Based Accelerometer Integrated With Channel Waveguides," Journal of Microelectromechanical Systems, vol. PP, no. 99, pp. 1-7, 2012.

4) Reference removed by TPOC on 2/19/13.

5) A. G. Krause, M. Winger, T. D. Blasius, Q. Lin, and O. Painter, "A microchip optomechanical accelerometer," arXiv:1203.5730, Mar. 2012.

6) J. Chan, T. P. M. Alegre, A. H. Safavi-Naeini, J. T. Hill, A. Krause, S. Groblacher, M. Aspelmeyer, and O. Painter, "Laser cooling of a nanomechanical oscillator into its quantum ground state," Nature, vol. 478, no. 7367, pp. 89–92, Oct. 2011.

7) G. Anetsberger, E. Gavartin, O. Arcizet, Q. P. Unterreithmeier, E. M. Weig, M. L. Gorodetsky, J. P. Kotthaus, and T. J. Kippenberg, "Measuring nanomechanical motion with an imprecision below the standard quantum limit," Phys. Rev. A, vol. 82, no. 6, p. 061804, Dec. 2010.

8) Q. Lin, J. Rosenberg, X. Jiang, K. J. Vahala, and O. Painter, "Mechanical Oscillation and Cooling Actuated by the Optical Gradient Force," Phys. Rev. Lett., vol. 103, no. 10, p. 103601, 2009.

KEYWORDS: Accelerometer, optomechanics, optics, MEMS, Fabry-Perot cavity, radiation pressure, optical cooling

ST13A-003 TITLE: Development of Gravitational Radiation Technology for Military Applications

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Demonstrate key technologies to enable application of gravitational radiation theory and research to military communications and navigation.

DESCRIPTION: There is a need for world-wide communications and navigation systems which do not need a sky-view link or line-of-sight and which are less vulnerable to threat activity. Satellite communication and navigation systems are vulnerable to interdiction and are expensive to maintain and operate.

One, very high risk approach is the adaptation of gravitational radiation (GR) to communications. GR is unaffected by obstructions such as the mass of the earth and thus offers a promise of world-wide, ground-based communications and navigation systems.

The scientific communities of the United States and other countries have devoted substantial resources to GR theory development, technology development, and experimentation to observe cosmological radiation. The first scientific experiments to detect GR were performed in the U.S. with weber bars. More recently, the U.S. has expended significant resources in developing the science and technologies for the Laser Interferometer Gravitational-Wave Observatory (LIGO). Foreign countries are also investing in research in similar activities such as MiniGRAIL (in The Netherlands), Virgo (in Italy), GEO 600 (in Germany), and TAMA 300 (in Japan). The scientific community is optimistic that GR will be directly detected within the next decade.

The transition of the GR science and technologies to military GR applications requires significant additional innovative research in several enabling technology areas beyond those of interest to the cosmological GR researchers. A successful GR communications system will require both a GR transmitter and a GR receiver. Current technology development is focused solely on GR detectors. The system needs to allow adequate bandwidth for communications. Current scientific GR detectors operate in the sub-Hz to few KHz range. The size of the GR system needs to be militarily useful. The current LIGO systems in Washington and Louisiana have detector arms several kilometers long. Implicit in the above is the most significant challenge, i.e., the detection of gravitational radiation. GR has not yet been directly detected.

This topic seeks innovative concepts for the application of GR to military communications. The concept should be supported by scientific literature or analysis based upon general relativity theory or quantum mechanics theory. The concept should provide sufficient detail to permit the high-level visualization of a system and the identification of key technologies that need to be developed. A field or laboratory validation of one or more key technologies is essential. The maturation of the concept should be phased with definitive advancements in technology.

PHASE I: Develop the underlying scientific approach to achieving a GR-based military communications system. Define the underlying technologies required to implement the system. Perform an analysis of the proposed system to include an estimate of the magnitude of GR emitted and an estimate of the sensitivity of the GR receiver.

PHASE II: Conduct an experiment to demonstrate one or more of the critical technologies needed to implement a system. The focus should be on the generation and detection of a GR carrier wave and not on the transmission of information. A fully successful experiment would result in the generation and detection of GR.

PHASE III: Initially, a successful GR communications system could replace existing high-priority communications with ground-based systems to reduce vulnerability. Eventually, it could replace satellite-based communications and navigations systems. Eventually a successful GR communications system would replace existing high capacity, long-haul point-to-point communications systems. This would reduce requirements for extensive ground infrastructure and maintenance.

REFERENCES:
1) Stephen J. Minter, Kirk Wegter-McNelly, Raymond, Y. Chiao, "Do Mirrors for Gravitational Waves Exist?" arXiv.org, "http://arxiv.org/abs/0903.0661".

2) Robert M. L. Baker, Jr., "The Li-Baked High Frequency Relic Gravitational Wave Detector," 12 August 2010, "http://gravwave.com/docs/2010 Russia Lect .ppt".

3) R. Clive Woods, Robert M.L. Baker, Fangyu Li, Gary V. Stephenson, Eric W. Davis, Andrew W. Beckwith, "A New Theoretical Technique for the Measurement of High-Frequency Relic Gravitational Waves," Journal of Modern Physics, 2011, 2,498-518, "http://www.scirp.org/journal/PaperInformation.aspx?paperID=5625"

4) L. Gottardi, A. de Waard, A. Usenko, and G. Frossati, "Sensitivity of the spherical gravitational wave detector MiniGRAIL operating at 5 K.", 1 May 2007, "http://arxiv.org/pdf/0705.0122v1.pdf"

5) Website: High Frequency Gravitational-Wave Detector, "http://www.sr.bham.ac.uk/gravity/project.php?project=MHzDetector".

KEYWORDS: gravitational radiation, gravitational waves, general relativity, quantum mechanics

ST13A-004 TITLE: <u>A Flexible and Extensible Solution to Incorporating New RF Devices and Capabilities into EW/ ISR Networks</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a solution that will allow for seamless insertion of new Radio Frequency (RF) devices and capabilities into EW/ISR networks. The newly added devices/capabilities should be readily available for providing services to the various applications running on the network. The goal is to support addition of new devices to multifunction networks in the field, without software changes elsewhere in the network.

DESCRIPTION: In military applications, RF devices constitute a heterogeneous network of receivers/ transmitters deployed primarily for the purpose of communicating tactical information. However, current RF devices are highly versatile and thus have the potential of fulfilling various functions in support of various tasks such as Situational Awareness, Electronic Warfare/Intelligence, Surveillance and Reconnaissance (EW/ISR). In the highly dynamic warfare environment, such EW/ISR networks should be easily extendable to incorporate new device types and to support additional applications [1].

One of the prerequisites for achieving this goal is the development of a language that can be used to describe both the capabilities of RF components and their current operational status. While some limited capabilities of this kind could be achieved by the use of XML coupled with an appropriate DTD [2], such an approach would be limited by the XML's lack of formal semantics. In particular, descriptions of device capabilities would have to be provided in a strictly prescribed format in order to be processed by the network infrastructure. Exchange of capability descriptions would consume substantial bandwidth, since complete descriptions would need to be sent. And finally, any extension of the device types or status information would require a modification of the software that interprets XML descriptions.

To avoid the above-described problems, this topic seeks development and/or specialization of a representation with formal, computer-processable semantics. It is highly desirable that the representation be based on a standard language. Examples of such semantic languages are Web Ontology Language (OWL) [3] and Rule Interchange Format (RIF) [4]. Prior work in this area has resulted in an ontology to describe the various aspects of the RF device structure and functionality [5]. However, this ontology is not sufficient for describing all of the characteristics of RF devices and their operational status needed for an EW/ISR network. Moreover, this work has not been demonstrated in relevant scenarios. The development of such an ontology is a complex task since it requires not only coverage of the relevant concepts of the domain, including complex relationships among the concepts, but also representing the concepts and the structures of knowledge in a form that a wide and diverse community of RF experts can agree on.

Furthermore, this topic seeks innovative research on automated tools that can automatically incorporate new devices into an RF Situation Awareness or EW/ISR network. The research should result in a solution that demonstrates seamless incorporation and use of the descriptions of RF components and their status by the network infrastructure.

PHASE I: Develop an ontology appropriate for describing typical RF devices and device status information, relevant for use of those devices to support EW/ISR tasks. Select a standards-based representation language and propose any extensions to the language that are necessary to effectively represent the ontology. Assess the limits of expressiveness of the ontology and of the language (as extended) with respect to both current and future RF devices and device status. Develop scenarios for testing the use of the ontology and language in a command and control system that selects an RF device to carry out a specified reception, transmission and/or processing task. Demonstrate the developed solution in a simulated environment. Interact with organizations and programs that may be users of the technology to assess requirements and improve their understanding of its benefits.

PHASE II: Evolve the ontology and extend the language as needed. Design and implement a run time prototype system that supports use of the descriptions of RF components and their status in a command and control system that selects an RF device to carry out specified reception, transmission and/or processing tasks. Develop a test environment for evaluating the run time system under the scenarios developed in Phase I. Carry out evaluation experiments accordingly. Interact with organizations and programs that may be users of the technology and adjust the ontology, language, run time system design, implementation strategy, scenarios and tests to maximize probability of successful adoption.

PHASE III DUAL USE APPLICATIONS: There is a critical military need for RF situational awareness and other EW/ISR capabilities that exploit large numbers of networked sensors and transmitters. Work is ongoing on methods to exploit RF devices already in the field for other purposes to support such capabilities [1], reducing or eliminating the cost of deploying special-purpose devices. Products based on the technology developed in this project will more readily extend to incorporate a larger range of devices, thus facilitating more rapid deployment and wider availability of the new EW/ISR network capabilities such as RF situational awareness. Similarly, benefits are expected in command and control systems for commercial RF device networks. One expected application is real-time reallocation of spectrum among multiple cellular and public safety wireless networks enabling increased civil data communications in normal conditions and increased public safety communications in emergency situations without increasing total spectrum requirements. Achieving this benefit requires broad-area real-time RF situational awareness, which will be made more affordable and more precise through flexible addition of heterogeneous devices to the sensor network as enabled by the results of this project.

REFERENCES:
1) Advanced RF Mapping (RadioMap) Program. Solicitation Number: DARPA-BAA-12-26. Defense Advanced Research Projects Agency, March 27, 2012.

2) Extensible Markup Language (XML) 1.0 (Fifth Edition). W3C Recommendation, 26 November 2008.

3) OWL Web Ontology Language Overview. W3C Recommendation, 10 February 2004.

4) RIF Overview. W3C Working Group Note, 22 June 2010.

5) Wireless Innovation Forum "Description of the Cognitive Radio Ontology", Technical Report WINNF-10-S-0007, September 30 2010. Available at http://groups.winnforum.org/d/do/ 3370.

KEYWORDS: RF devices, device capabilities, capability descriptions, ontology for RF devices.

ST13A-005 TITLE: Modeling and Optimizing Turbines for Unsteady Flow

TECHNOLOGY AREAS: Air Platform, Ground/Sea Vehicles

OBJECTIVE: Develop an analytical software tool capable of modeling and optimizing turbine components for unsteady flow conditions.

DESCRIPTION: Conventional gas turbine engines rely on Constant Pressure Combustion (CPC) to generate the enthalpy needed to provide the horsepower and thrust that our warfighters need. Unfortunately, CPC is a very inefficient process and approximately 30-40% of the energy contained in a unit of fuel is wasted. The ability to create greater efficiency and power density using current gas turbine technology and design is extremely limited and the marginal rate of return in dollars and technology invested versus efficiency and power density is decreasing. The DoD and Industry spends millions of dollars to achieve fractions of a percent increase in fuel efficiency. Increased SFC directly translates into greater range, endurance and capability for our military.

Pressure Gain Combustion (PGC) addresses the largest source of inefficiency in gas turbine engines and offers the greatest potential for improving combustion efficiency and reducing Specific Fuel Consumption (SFC). It is estimated that integrating this technology into current or future engines will decrease SFC by 10-20% and increase power density by 20%. Although PGC has demonstrated efficiency, it is not without its drawbacks. Almost every PGC concept developed whether Pulse Detonation Engines (PDE), Rotating Detonation Engines (RDE) or Wave Rotor introduces unsteady flow conditions. Conventional gas turbines are optimized for steady flow conditions and introduction of unsteadiness in pressure, temperature, and/or swirl angle can have detrimental effects on turbine efficiency. Without the development of a highly efficient turbine capable of operating across a wide range of temperatures, pressures, and incidence angles, all gains made by the combustors will be lost when PGCs are integrated with turbines. Efficient turbines capable of operating in highly unsteady regimes are needed in order to fully achieve the energy benefits PGCs offer. The current State of the Art for this technology is TRL 2. At the end of this STTR it is anticipated that an optimized turbine can be designed and tested to validate the software.

PHASE I: Develop an analytical software tool capable of modeling and optimizing turbine components in unsteady flow. Select current or previous PGC data (unsteady flow to the turbine) as input to develop an analytical software tool capable of modeling and optimizing turbine components for unsteady flow conditions and increasing efficiency. The Phase I deliverables will include monthly status reports and a Final report.

PHASE II: Utilize the software tool developed in Phase I to design and manufacture an optimized first stage high pressure turbine and test it in an operationally relevant environment. The target Technology Readiness Level (TRL) for this component should be 4-5. Deliverables include: a prototype of the optimized high pressure turbine, monthly status reports, and a final report that contains test data from the optimized component.

PHASE III: This technology is applicable to the Navy, Air Force, Army, and Marine Corps gas turbine engines and their use in aircraft, ground vehicle, and ship propulsion. Significant fuel cost savings, reduced logistics footprint, and an overall increase in turbine efficiencies will reduce dependency on fuel and have a profound impact on national security. This technology has commercial gas turbine application in aircraft and commercial ship propulsion; and gas turbine - power generation. The ability to model and optimize turbine components for unsteady flow conditions is essential in the ability to design pressure gain combustion turbine engines in the future. Pressure gain combustion technology has the potential to reduce specific fuel consumption by 20% and increase power density by 20%.

REFERENCES:
1) Mattingly, J. D., “Elements of Gas Turbine Propulsion”, McGraw-Hill, 1996.

KEYWORDS: Turbines, Pressure Gain Combustion, Pulse Detonation, Rotating Detonation, Wave Rotor

ST13A-006 TITLE: <u>Novel Extensible Design Approaches for Advanced Aircraft Composite Structural Architectures</u>

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Define a low-level, stochastically verified, composite structural toolset geared towards expediting aircraft design and development, while at the same time leveraging a building-block approach to structural verification for enhanced airframe assurance.

DESCRIPTION: Advanced composites enable high performance aerospace structures, including extensive tailoring to particular applications, fastener elimination, weight reduction, improvements in fatigue resistance, and corrosion prevention. Some essential challenges for modern composite design, fabrication, and certification include the integration of structural design detail with repeatable manufacturing processes, which must include both material and process control. Typically, the design problem is dominated by considerations of design details, manufacturing flaws, and service damage, all of which cause local stress concentrations.

Robust approaches to structural assurance explore strength, fatigue, and damage tolerance issues, and tend to have a high dependency on multiscale sample tests. This design and testing approach tends to have enormous cost and schedule impacts, effectively raising the barrier to entry of advanced composite structures into major DoD platforms.

This effort intends to develop structural architectures that speed development and qualification of composite aircraft, which has broad benefits to DoD, DARPA, and the private sector in reducing cost, increasing content re-use, and improving time-to-market.

In particular, novel solutions are sought that would allow extensive reuse of parametric elements in structural design of composites to achieve expedited design, verification, validation, and airworthiness certification or qualification. By raising the level of structural design abstraction to higher orders, both design engineering and verification activities could be effectively abbreviated while increasing design confidence.

While conventional design processes use a set of material allowables verified at couponlevel, the end goal of this effort would be to develop a stochastically validated, open, extensible database typical aircraft component geometries, which include allowable properties, based on key parameters for geometry, materials, and defined manufacturing process standards.

These properties should be applicable to a defined set of configurations for key primary and secondary structural elements, including for example, spars, ribs, skins, doors, landing gear, and associated composite to composite and composite to metal joints. Each of these components should include definition of parameters that permit sizing to necessary loads, and consideration of buckling and other potential failure modes of the structures based on probable load applications.

For reference and guidance, one may refer to the government publication, ANC18, which defines properties for wooden aircraft structural materials and guidelines for structural member and joint design. Although obsolete, publication ANC-18 offers relevant guidance to this effort, because it provides a novel set of design rules for non-homogenous structures. Wood, considered the original filamental composite, is actually a more complex material to design with, possessing more key parameters on type, condition, and alignment of the material with loads than are normally considered for modern composites in airframes.

PHASE I: Design and specify a preferred material set and set of basic components, perform analytic justification of chosen parametric geometries. Define robust approach for uncertainty characterization and tracking. Develop an analysis of predicted performance, and define key technological milestones. Phase I deliverables will include a description of the proposed material set, proposed component set, analytic justification of broad aerospace applicability, and definition of processes required to quantify and track performance uncertainty from design through certification.

PHASE II: Develop, demonstrate, and validate the basic approach to component parametric definition, stochastic verification, and quantification and tracking of uncertainties. It is anticipated that this demonstration will occur in a laboratory setting, but demonstrate multiscale parametric element application, uncertainty quantification, stochastic verification, design application, process verification, and representative simulation in a certification process flow.

PHASE III: This novel architectural approach has potential for use in civil-certified aircraft structures, inclusive of aircraft certified to 14CFR PART 23 and 14 CFR PART 25. If successful, this methodology has the potential to directly transition to the Air Force Research Laboratory's Composites Affordability Initiative. Additionally, future unmanned aircraft programs, including demonstration programs executed by DARPA, may have particular benefit from this structural architecture approach and associated methodology. An alternate military transition path would be inclusion of this structural approach into a future aircraft program of a record.

REFERENCES:
1) MILHDBK17, Composite Materials Handbook

2) ANC18 Design of Wood Aircraft Structures, Code of Federal Regulations (CFR), Title 14 (Aeronautics and Space), 14 CFR Part 23, and 14 CFR Part 25, FAA Advisory Circular AC 20-107B "Composite Aircraft Structure"

3) Code of Federal Regulations (CFR), Title 14 (Aeronautics and Space), 14 CFR Part 23, and 14 CFR Part 25,

4) FAA Advisory Circular AC 20-107B "Composite Aircraft Structure"

KEYWORDS: Composites; Design; Paramtric; Certification