NAVY
STTR 12.A PROPOSAL SUBMISSION

INTRODUCTION:

The responsibility for the implementation, administration and management of the Navy STTR Program is with the Office of Naval Research (ONR). The Navy STTR Program Manager is Mr. Steve Sullivan. If you have questions of a general nature regarding the Navy's STTR Program, contact Mr. Sullivan (steven.sullivan@navy.mil). For general questions regarding NAVAIR topics N12A-T001 through N12A-T007, please contact the NAVAIR STTR Program Manager, Dusty Lang (navair.sbir@navy.mil.). For inquiries or problems with electronic submission, contact the DoD Help Desk at 1-866-724-7457 (8:00 a.m. to 5:00 p.m. ET). For technical questions about a topic, you may contact the Topic Authors listed under each topic before **27 February 2012**. Beginning **27 February**, for technical questions you must use the SITIS system **www.dodsbir.net/sitis** or go to the DoD Web site at **http://www.acq.osd.mil/sadbu/sbir** for more information.

The Navy's STTR Program is a mission-oriented program that integrates the needs and requirements of the Navy's Fleet through R&D topics that have dual-use potential, but primarily address the needs of the Navy. Companies are encouraged to address the manufacturing needs of the Defense Sector in their proposals. Information on the Navy STTR Program can be found on the Navy STTR Web site at **http://www.onr.navy.mil/sbir.** Additional information pertaining to the Department of the Navy's mission can be obtained by viewing the Web site at **http://www.navy.mil.**

PHASE I PROPOSAL SUBMISSION:

Read the DoD front section of this solicitation for detailed instructions on proposal format, submission instructions and program requirements. When you prepare your proposal, keep in mind that Phase I should address the feasibility of a solution to the topic. The Navy only accepts Phase I proposals with a base effort not exceeding $80,000 and with the option not exceeding $70,000. The technical period of performance for the Phase I base should be 7 months. The Phase I option should be 6 months and address the transition into the Phase II effort. Phase I options are typically only funded after the decision to fund the Phase II has been made. Phase I technical proposals, including the option, have a 25-page limit (see section 3.4). The Navy will evaluate and select Phase I proposals using scientific review criteria based upon technical merit and other criteria as discussed in this solicitation document. Due to limited funding, the Navy reserves the right to limit awards under any topic and only proposals considered to be of superior quality will be funded. The Navy typically provides a firm fixed price contract or awards a small purchase agreement as a Phase I award.

All proposal submissions to the Navy STTR Program must be submitted electronically. It is mandatory that the **entire** technical proposal, DoD Proposal Cover Sheet, Cost Proposal, and the Company Commercialization Report are submitted electronically through the DoD SBIR/STTR Submission Web site at **http://www.dodsbir.net/submission**. This site will lead you through the process for submitting your technical proposal and all of the sections electronically. Each of these documents is submitted separately through the Web site. To verify that your technical proposal has been received, click on the "Check Upload" icon to view your uploaded technical proposal. If you have any questions or problems with the electronic submission contact the DoD SBIR Helpdesk at 1-866-724-7457 (8:00 a.m. to 5:00 p.m. EST). Your proposal **must** be submitted via the submission site before **6:00 a.m. ET, Wednesday, 28 March 2012**. An electronic signature is not required when you submit your proposal over the Internet.

***** A small business concern must negotiate a written agreement between the small business and the research institution allocating intellectual property rights and rights to carry out follow-on research, development, or commercialization (ref: DoD Section 3.5(e) Agreement between the Small Business and Research Institution). It is requested that all Navy STTR offerors upload this agreement as part of the STTR proposal submission - it will not count towards the page limit. If you are selected for award, and have not transmitted the agreement to the point of contact identified in the selection notice, you will be required to submit the signed agreement within 18 calendar days or forfeit your selection. *****

Within one week of the Solicitation closing, you will receive notification via e-mail that your proposal has been received and processed for evaluation by the Navy. Please make sure that your e-mail address is entered correctly on your proposal coversheet or you will not receive a notification.

PHASE I SUMMARY REPORT:

All awardees must submit a non-proprietary summary of their final report (without any proprietary or data rights markings) through the Navy SBIR website. Submit the summary at: **http://www.onr.navy.mil/sbir**, click on "Submission", and then click on "Submit a Phase I or II Summary Report". A template is provided for you to complete. This summary, once approved, may be publicly accessible via the Navy's Search Database.

PHASE II PROPOSAL SUBMISSION:

Phase II proposal submission is strictly by invitation. Only those Phase I awardees who achieved success in Phase I, measuring the results achieved against the criteria contained in the DoD solicitation preface, section 4.3, "Evaluation Criteria – Phase II", will be invited to submit a Phase II proposal. If you have been invited to participate, follow the instructions provided in the invitation. The Navy will evaluate and select Phase II proposals using the evaluation criteria in the DoD solicitation, Section 4.3. All Phase II proposals must be submitted electronically through the DoD SBIR/STTR Submission Web site. The Navy does NOT participate in the FAST TRACK Program.

The Navy STTR Program structures Phase II contracts in a way that allows for increased funding levels based on the project's transition potential. This is called the Phase II.5 and is accomplished through either multiple options that may range from $250,000 to $1,000,000 each, substantial expansions to the existing contract, or a second Phase II award. For existing Phase II contracts, the goals of Phase II.5 can be attained through contract expansions, some of which may exceed the $1,000,000 recommended limits for Phase II awards.

All awardees, during the second year of the Phase II, must attend a one-day Transition Assistance Program (TAP) meeting. This meeting is typically held during the summer in the Washington, D.C. area. Information can be obtained at **http://www.dawnbreaker.com/navytap**. Awardees will be contacted separately regarding this program. It is recommended that Phase II cost estimates include travel to Washington, D.C. for this event.

As with the Phase I award, Phase II award winners must electronically submit a Phase II summary through the Navy SBIR/STTR Web site at the end of their Phase II.

ADDITIONAL NOTES:

1. The Naval Academy, the Naval Postgraduate School and other military academies are government organizations and therefore do NOT qualify as partnering research institutions.

However, if an otherwise-qualifying proposal presents a compelling need for participation by such an institution (or any other government organization), then, subject to a waiver granted by the Small Business Administration (SBA), this organization can participate in the role of a subcontractor. Such a government subcontractor may be proposed only IN ADDITION TO the partnering research institution; and the contract award will be contingent on the receipt of the SBA waiver.

2. Due to the short time frame associated with Phase 1 of the STTR process, the Navy does not recommend the submission of Phase 1 proposals that require the use of Human Subjects, Animal Testing, or Recombinant DNA. For example, the ability to obtain Institutional Review Board (IRB) approval for proposals that involve human subjects can take 6-12 months, and that lengthy process can be at odds with the Phase I time to award goals. Before the Navy makes any award that involves an IRB or similar approval requirement, the proposer must demonstrate compliance with relevant regulatory approval requirements that pertain to proposals involving human, animal or recombinant DNA protocols. It will not impact our evaluation, but requiring IRB approval may delay the start time of the Phase I award and if approvals are not obtained within 6 months of notification of selection, the award may be terminated. If you are proposing human, animal and recombinant DNA use under a phase I or phase II proposal, you should view the requirements at **http://www.onr.navy.mil/About-ONR/compliance-protections/Research-Protections.aspx.** This website provides guidance and notes approvals that may be required before contract/work can begin.

PHASE I PROPOSAL SUBMISSION CHECKLIST:

All of the following criteria <u>must be met</u> or your proposal will be REJECTED.

1. **Include a header with company name, proposal number and topic number to each page of your technical proposal.**

2. **Include tasks to be completed during the option period and include the costs in the cost proposal.**

3. **Break out subcontractor, material, and travel costs in detail. Use the "Explanatory Material Field" in the DoD cost proposal worksheet for this information, if necessary.**

4. **The Phase I proposed cost for the base effort does not exceed $80,000. The Phase I Option proposed cost does not exceed $70,000. The costs for the base and option are clearly separate, and identified on the Proposal Cover Sheet, in the cost proposal, and in the work plan section of the proposal.**

5. **Upload your technical proposal and the DoD Proposal Cover Sheet, the DoD Company Commercialization Report, and Cost Proposal electronically through the DoD submission site by 6:00 a.m. ET, 28 March 2012.**

6. **If the Agreement between the Small Business and Research Institution is not included with the proposal submission, it MUST be provided within 18 calendar days after receipt of the award selection notice, or the award selection will be forfeited.**

7. **After uploading your file on the DoD submission site, review it to ensure that it appears correctly. Contact the DoD SBIR/STTR Help Desk immediately with any problems.**

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NAVY STTR 12.A Topic Descriptions

N12A-T001 TITLE: Integral Fuel Tank Self-sealing Protection

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: PMA 290

OBJECTIVE: Develop technology capable of providing lightweight self-sealing capability to prevent fuel loss from ballistic impacts for combat aircraft fuel tanks.

DESCRIPTION: Lightweight self-sealing capability to prevent fuel loss from ballistic impacts is a critical combat aircraft performance objective. Currently, fuel tanks are protected with ballistic liners, internal self-sealing layers or self-sealing bladders with limited success. The bladders consist of multiple layers. The internal (sandwiched) layer of material swells upon contact with fuel, with the intended result of resealing the bladder, after puncture, to prevent fuel loss. The current specification required resealing within 2 minutes after puncture.

Issues with current technology include excessive weight and unreliable reproducibility in self-sealing layer resulting in poor ballistic wound closure and additional fuel loss. As ballistic impact most typically occurs on the underside of the aircraft, protection is not necessary on the top of the fuel tank. Reduction of material to cover only the vulnerable areas could result in reduced weight. Additionally, a more reliable and consistent method of ballistic protection is sought.

The goal of this STTR is installation/application of a lightweight ballistic protection technology to vulnerable areas of existing integral fuel tank structure. Design concerns include balancing level of ballistic protection with aircraft weight and stiffness. Ballistic protection includes impacts from both tumbled and fully aligned small caliber Armor Piercing (AP), AP Incendiary (API), Ball rounds and missile warhead fragments. New technologies should be capable of providing fuel containment within 2 minutes (threshold), with 30 seconds the ultimate goal, at -40°F and at ambient temperatures. New technologies should perform with commercial Jet A (including military additives) and a 50/50 blend of current jet fuel and bio fuel with minimum aromatic content of 8%. Design should not interfere with fuel purity, fuel transfer and surrounding aircraft structure or equipment. Threshold leak rates from new approaches will be tested using existing aircraft fuel tanks after a simulated penetration by a 50 caliber round at -40°F and at ambient temperatures.

PHASE I: Develop approaches to provide lightweight ballistic protection capable of meeting required specifications for existing aircraft fuel tanks. Demonstrate the feasibility of the recommended approach. Identify concepts and methods to be used to install/apply this new technology to existing fuel tanks.

PHASE II: Develop and demonstrate prototype ballistic protection capabilities using a panel from a current fuel tank design under a range of ballistic rounds, meeting desired leakage limits.

PHASE III: Complete validation and verification of ballistic protection technology. Transition technology for implementation on existing fixed wing aircraft or auxiliary fuel tank.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Lightweight fuel tank protection can transfer to commercial aviation, automotive and transportation industries, providing protection of tanks containing fuel, hazardous materials and other liquids.

REFERENCES:
1. MIL-DTL-5578 (Self-sealing Fuel Tank) D (8/2008) http://www.everyspec.com/MIL-SPECS/MIL+SPECS+(MIL-DTL)/MIL-DTL-5578D_13567/

2. MIL-DTL-27422(Ballistic Tolerant Tank) D (1/2007) http://www.everyspec.com/MIL-SPECS/MIL+SPECS+(MIL-DTL)/MIL-DTL-27422D_20366/

3. MIL-DTL-5624 (JP-5) U (11/2008) http://www.everyspec.com/MIL-SPECS/MIL+SPECS+(MIL-DTL)/MIL-DTL-5624U_5535/

4. MIL-DTL-83133 (JP-8) G (4/2010) http://www.everyspec.com/MIL-SPECS/MIL+SPECS+(MIL-DTL)/MIL-DTL-83133E_14547/

KEYWORDS: Self-sealing, integral fuel tank, impact, leakage, projectile, ballistic protection

N12A-T002 TITLE: Exploiting Polarimetry in Littoral Surveillance

TECHNOLOGY AREAS: Air Platform, Sensors

ACQUISITION PROGRAM: PMA 266

OBJECTIVE: Develop polarimetric imaging techniques to significantly improve small maritime target detection and classification capabilities.

DESCRIPTION: The move of naval operations into the littorals exposes our ships to the small boat terrorist threat. The first step in discerning the intention of any particular small boat is to classify and fingerprint it so it can be observed over an extended period of time. Currently, inverse synthetic aperture radar (ISAR) techniques are used for ship classification. Large ships tend to have a rich set of discernable features making classification relatively straightforward. However, small boats rarely have such a rich set of discernable features.

Polarimetric techniques in synthetic aperture radar (SAR) over land have shown the potential for improved ship classification performance using SAR polarimetric techniques By leveraging the expanded feature set available from a combination of polarimetric SAR and ISAR, a significant improvement in small boat classification performance seems possible. The expanded feature set includes both hard-body scattering characteristics and distinctive wake characteristics. The major challenge facing the community is that our knowledge about polarimetric ISAR and SAR phenomenology of small boats is very limited, and this prevents one from knowing how to interpret and exploit the scattering information for classification or identify how the robustness of polarimatric features, improves small boat classification (< 100 ft length). The targets of radar operation are the C- and X-bands.

PHASE I: Determine the feasibility of using polarimetric imaging techniques to significantly improve small maritime target detection and classification capabilities.

PHASE II: Demonstrate the technique using specific exploitable scattering characteristics to enable both fingerprinting and classification. Assess the robustness of the feature set as a function of radar band, resolution and viewing geometry.

PHASE III: Mature the polarimetric fingerprinting and classification approaches for real-time implementation. Transition the algorithms into a suitable tactical airborne radar system for use in the Fleet.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The techniques may be used with commercial overhead sensors for surveillance of the activity of fishing vessels as a part of regulation within the Extended Economic Zone (EEZ).

REFERENCES:
1. Margarit, G., Mallorquí, J. J., Fortuny-Guasch, J., López-Martínez, C. (2009). Phenomenological Vessel Scattering Study Based on Simulated Inverse SAR Imagery. IEEE Transactios on Geoscience and Remote Sensing, 47(4). doi:10.1109/TGRS.2008.2008443

2. Crisp, D. J., & Keevers, T. (2010, May 24-27). Comparison of ship detectors for polarimetric SAR Imagery. OCEANS 2010 IEEE - Sydney, pp. 1-8. doi:10.1109/OCEANSSYD.2010.5603581

3. Zhang, L., Zou, B., Wei, T., & Zhang, Y. (2007). Targets Detection and Analysis in Coastal Area Using Polarimetric SAR. Synthetic Aperture Radar, 2007. pp. 453 - 456. doi:10.1109/APSAR.2007.4418648

KEYWORDS: Polarimetric SAR; target decomposition; Polarimetric ISAR; Small Boat; Moving Target Detection; Vessel Identification

N12A-T003 TITLE: High-Power Semiconductor Laser in the 3.0- to 3.5-um Spectral Range

TECHNOLOGY AREAS: Air Platform, Sensors, Battlespace

ACQUISITION PROGRAM: PMA 264

OBJECTIVE: Develop a high-power semiconductor-based laser source operating at room temperature in the wavelength range between 3.0 and 3.5 um.

DESCRIPTION: High-power, reliable semiconductor laser sources in the wavelength range between 3.0 and 3.5 um are very desirable for a number of naval applications such as advanced chemical sensors, and laser identification detection and ranging (LIDAR). Current means to generate coherent optical radiation in this spectral band such as optical parametric oscillators (OPOs), super-continuum fiber sources, or Raman-shifted lasers are in too bulky in terms of size, weight and power (SWaP), too complicated of an architecture, or simply inefficient. Therefore, a semiconductor-based laser source in the 3.0- to-3.5- um range would significantly improve the development of next generation sensors.

While the coherent light sources at or near the 3-um spectral range have tremendous potential for numerous DoD applications, the availability of reliable, small-footprint and high-power semiconductor laser sources, in the wavelength range of interest, is very limited. Watts-level continuous wave (CW) quantum cascade lasers (QCLs) have been demonstrated at wavelengths as short as 3.76 um but the performance of QCLs drops significantly as the wavelength approaches 3.0 um. The main limitation comes from the presence of satellite valleys, which limit the band-offset available to build population inversion efficiently. New material systems such as highly strained InGaAs/Al(In)As, InGaAs/AlAsSb alloys on InP substrate, and/or InAs/AlSb on InAs substrates have been used to remedy this problem but only pulsed operation has been demonstrated so far. Many technological advances have been demonstrated in devices based on the concept of interband cascade lasers (ICLs), which constitute a great alternative to traditional QCLs, although CW power has not exceeded 100 mW at room temperature. Rapid progress has also been made recently in GaSb-based mid-infrared diode lasers and watt level output power was demonstrated in the range of 2.0 to 2.4 um. At ~2.9 um, CW operation with up to 200 mW at room temperature has been demonstrated with a broad area device. The performance of this class of diode lasers at wavelengths near 3 um is however limited by a variety of factors, including the confinement for hole carriers that decreases rapidly for laser structures with emission wavelengths longer than 3 um.

The goal of this topic is to seek the development of high-performance semiconductor laser sources with high CW power and excellent beam quality within the 3 um to 3.5 um spectral range, which consist of either a single semiconductor laser device or an integrated beam-combined semiconductor laser array with a single output aperture without using any external optical elements. Hybrid integration of laser array with external optical elements and/or electronics are often more cumbersome, bulky, costly and much less reliable platform and therefore undesirable for demanding field applications in harsh operating conditions.

PHASE I: Determine the feasibility of designing a semiconductor laser source operating within the spectral range of 3 - 3.5 um, operating at room temperature, and capable of producing 500 mW in CW mode with beam quality of M2 < 1.3. Provide a development plan that describes the power scaling architecture with a power and beam quality of the scaled device(s) at least 5-10 watts with M2<1.3.

PHASE II: Design and develop a prototype of the semiconductor laser source operating within the spectral range of 3 - 3.5 um, operating at room temperature, and produce at least 500 mW in CW mode with beam quality of M2 <

1.3. Assess the manufacturing yield and product reliability of the single laser or monolithically integrated laser array solution.

PHASE III: Fully develop and transition the high-performance semiconductor laser source architecture developed in the Phase II effort for maritime sensing, naval aviation LIDAR, and advanced chemical sensor applications.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The commercial sector can significantly benefit from this technology development in the areas of detection of toxic industrial gases, environmental monitoring, and non-invasive medical health monitoring and sensing.

REFERENCES:
1. Hosoda, T., Kipshidze, G., Shterengas, L., Suchalkin, S., and Belenky, G. (2009). 200 mW type I GaSb-based laser diodes operating at 3 µm: Role of waveguide width. Applied Physics Letters, 94(26). http://link.aip.org/link/doi/10.1063/1.3159819

2. Shterengas, L., Belenky, G. L., Kim, J. G., and Martinelli, R. U., (2004). Design of high-power room-temperature continuous-wave GaSb-based type-I quantum-well lasers with ? > 2.5 µm. Semiconductor Science and Technology, 19(5). doi:10.1088/0268-1242/19/5/016

KEYWORDS: QCL; mid-infrared; monolithic; semiconductor; beam combining; laser array

N12A-T004 TITLE: Bonded Joint Analysis Method

TECHNOLOGY AREAS: Air Platform, Weapons

ACQUISITION PROGRAM: PMA 242

OBJECTIVE: Develop an analytical method, failure criteria, and required material test methods to enable accurate predictions of failures on bonded composite structures.

DESCRIPTION: Modern research has attempted with some success to develop a mixed mode failure theory for adhesive bonds and ductile metals. The ABAQUS finite element software currently used within the Navy includes a cohesive zone element that represents either a composite layer’s interlaminar strength or an adhesive layer’s stiffness and strength. This element has several ways to combine tension and shear into a failure index, but no way to combine compression and shear or account for the multi-axial directions of these stresses. The Defense Science and Technology Organization in Australia performed some testing and observed the behavior of a structural adhesive under complex loading. The correlation to existing yield criteria was not particularly good but it highlighted the effect of combined stresses and need to account for them in a design.

The objective of this topic is to advance the state of the art by identifying a failure theory with a basis in basic material properties that can be employed during structural analysis and will result in quantified margins of safety for bonded joints. The combined failure theory should include, at the minimum, the full range of complex loading, the inclusion of that theory into a finite element analysis application, the test methods required to generate the needed material properties, and finally the validation of the method through the analysis and test of complexly loaded bonded structures. It should include all of the potential failure modes like adhesive failure, cohesive failure, and first-ply delamination of the composite adherands.

The method shall be compatible with commercially available finite element analysis software. Identification of material properties needed to support the analysis, and identification of, or development of appropriate test methods to measure those properties is an important part of the research. The research shall include the ability to quantify the effects of moisture and temperature into the analysis. Lastly, the research shall include demonstration of the ability to successfully predict failure of several distinct joint geometries and stress states.

PHASE I: Prove feasibility of a bonded joint failure theory for predicting cohesive, adhesive and adherand failures based on material characterization and finite element analysis methods.

PHASE II: Develop, demonstrate and verify the failure theory, and its implementation, with several types of adhesives and joint geometries. User defined materials, elements, or other modifications consistent with the finite element software's standard methods for accommodating user unique requirements are acceptable at this phase.

PHASE III: Verify failure theory against a larger variety of joint geometries, materials, and loadings. Implement in a finite element analysis software's (such as ABAQUS) standard library of options.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Bonded joints and their analysis are equally important to the department of defense and the private sector. There is also commercial potential for the analytical software companies that implement the method into their finite element analysis products.

REFERENCES:

1. Loss, K.R, & Kedward, K.T. (1984). Modeling and Analysis of Peel and Shear Stresses in Adhesively Bonded Joints. AIAA-1984-913, 222-231

2. Thouless, M.D. & Parmigiani, J.P. (2007). Mixed-Mode Cohesive-Zone Models for Delamination and Deflection in Composites. http://www-personal.umich.edu/~thouless/Riso(2007).pdf

3. Yang, Q.D., & Thouless, M.D. (2000).Mixed Mode Fracture Analysis of Plastically Deforming Adhesive Joints. http://www-personal.umich.edu/~thouless/Mixed-mode.pdf

KEYWORDS: bonded; joints; mixed-mode; adhesive; cohesive; analysis

N12A-T005 TITLE: High-Speed Electronically Tunable Fiber Optic Wavelength Filter

TECHNOLOGY AREAS: Air Platform, Information Systems

ACQUISITION PROGRAM: JSF

OBJECTIVE: Develop a high-speed, loss-free, electronically controlled tunable fiber-optic filter for avionic wavelength division multiplexing (WDM) applications.

DESCRIPTION: Reducing weight and space is a major concern of the avionic environment. One approach to reducing weight and size (as well as increasing system bandwidth and connectivity) is to replace the current system of numerous point-to-point links with a robust fiber-optic WDM network. WDM is a routing method whereby several data streams are multiplexed and transmitted over the same optical fiber cable. After transmission over fiber, the wavelengths are de-multiplexed and sent to different receivers . A high-speed tunable filter could be used to select across all wavelengths, retrieving and routing the data to specific receivers based on the tuning frequency of the filter. A wide range of tunable filters has been developed, however current tuning mechanisms, including thermal and mechanical stress , are limited to millisecond range tuning speeds. For avionic applications, the tunable filter must operate from -40 to +100ºC and tuning speed must be 1 microsecond or less across the C-band of the International Telecommunication Union (ITU) wavelength grid. With a microsecond switching speed , tunable filters could also be used as a routing element to control network traffic.

PHASE I: Develop an innovative tunable filter concept. Demonstrate the feasibility of the design via modeling and simulation.

PHASE II: Demonstrate the operation of a prototype tunable filter over a -40 to 100ºC temperature range. Design and optimize the tunable filter package and tuning/control circuits.

PHASE III: Conduct environmental testing for tunable wavelength filter. Develop plan for mass production and transition into a WDM network for Joint Strike Fighter (JSF).

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Large-scale WDM networks are used by communication companies for high-bandwidth applications such as Fiber to the Home or Fiber to the Office.

REFERENCES:

1. Iocco, A., Limberger, H.G., Salathe, R.P., Everall, L.A., Chisholm, K.E., Williams, J.A.R., & Bennion, I. (1999). Bragg Grating Fast Tunable Filter for Wavelength Division Multiplexing. Journal of Lightwave Technology, 17(7) 1217.

2. Mahmoud, M., & Ghassemlooy, Z. (2003). Tunable Fiber Bragg Gratings Modeling and Simulation. Proceedings of the 36th Annual Simulation Symposium.

3. Girard, A. (2000). Guide to WDM Technology and Testing: A Unique Reference for the Fiber-Optic Industry. Quebec City, Canada: EXFO Electro-Optical Engineering Inc.

4. Huang, Y., Ma, J., & Ho, S. (2007, September 16). Integrated High Speed Tunable Filter Based on Super Compact Grating. Frontiers in Optics, p.FWR6. http://www.opticsinfobase.org/abstract.cfm?uri=FiO-2007-FWR6

KEYWORDS: Fiber Optics; Tunable Filter; Analog; Digital; WDM networking

N12A-T006 TITLE: <u>Total Fatigue Life Assessment of Complicated Structures</u>

TECHNOLOGY AREAS: Air Platform, Space Platforms

ACQUISITION PROGRAM: PMA 275

OBJECTIVE: Develop innovative concepts for coupling analytical and/or numerical techniques to evaluate total fatigue life of structures involving complicated two-dimensional (2D) and three dimensional (3D) cracks of planar and non-planar shapes.

DESCRIPTION: Cracks in aircraft structural components are of complex shapes and subjected to complicated load histories. Too often, crack growth analysis is carried out by oversimplifying the problem through the use of simple crack shapes and one dominant loading. This results in less rigorous stress intensity factor (SIF) values that are needed in crack growth analysis and therefore unrealistic crack growth life values. Accurate SIF values are needed for predicting reliable total life assessment of complex structures under complicated loading histories.

A number of numerical techniques such as Finite Element Method (FEM), Boundary Element Method (BEM) and a few others have been used in SIF evaluation for cracks of complex shapes and geometries. The primary disadvantages of these methods are that very fine meshes are required to accurately capture the strengths of singularities near the crack tip. Additionally, when crack growth is considered, in high-gradient residual as well as load-induced stress-fields, such fine meshes have to be continuously regenerated making these methods computationally very prohibitive. These solution techniques are not suitable for mixed mode crack growth problems.

Fundamentally novel and innovative methods are sought for the analyses of non-collinear mixed mode fatigue crack-growth in two-dimensions, and non-planar mixed mode crack growth in three dimensions, of arbitrarily shaped embedded and/or surface flaws in complicated geometries of thin and thick-section aerospace structural components. Analytical and/or numerical methods should be capable of generating accurate SIF values under various loading conditions involving load redistribution, mulit-element cracking, and complex residual stress-fields in an efficient way with less computational complexities.

Innovative coupled analytical and/or numerical techniques may increase the overall accuracy of the SIF solution to reliably predict total life of structural components efficiently.

PHASE I: Develop an innovative approach for coupling analytical and/or numerical techniques and demonstrate the feasibility of the developed technique.

PHASE II: Fully develop the concept into a prototype fatigue life and crack growth methodology that can be used in conjunction with commercial finite element analysis software packages.

PHASE III: Transition the developed fatigue life assessment and crack growth analysis package working with government and industry partners.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Methods and techniques developed can be folded into commercial finite element analysis packages as a module for broad use in a wide variety of industrial applications in estimating the life of a variety of safety critical structures.

REFERENCES:
1. Sutradhar, A., Paulino, G. H. & Gray, L. J. (2008). Symmetric Galerkin boundary element method. Berlin: Springer-Verlag.

2. Frangi, A. & Novati, G. (1996). Symmetric BE method in two dimensional elasticity: Evaluation of double integrals for curved elements. Computational Mechanics, 19, 58-68.

3. Han , Z. D. & Atluri, S. N. (2002). SGBEM – FEM alternating method for analyzing 3D surface cracks and their fatigue-growth. CMES: Computer Modeling in Engineering & Sciences, 3 (6), 699-716.

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KEYWORDS: Stress Intensity Factor; fatigue life; Finite Element Method; Boundary Element Method; Crack Growth; Computational Method

N12A-T007 TITLE: Early Damage State Detection in Gearbox Components Via Acoustic Emission

TECHNOLOGY AREAS: Air Platform, Sensors

ACQUISITION PROGRAM: PMA 299

OBJECTIVE: Develop a reliable acoustic emission monitoring capability to detect the very early stages of crack initiation and propagation in rotating gearbox components in real time.

DESCRIPTION: Vibration techniques for monitoring the health of rotating components have been well established, but a key shortcoming is the capability to identify the initial damage states of crack initiation and short crack propagation. Acoustic emission techniques have been used for some time in monitoring the health of static structures. The technology holds promise for early detection of cracks in noisy applications such as rotating machinery, if techniques are employed capable of pulling the signal of interest out of background noise generated by turbine engines, rotors, propellers and the elevated noise levels of the gearbox.

Certain highly loaded rotating gearbox components with fast crack propagation rates require early detection to mitigate risk. Critical, highly loaded components in aviation gearboxes include gears, splines and bearings; the health of these components is a key safety driver. Acoustic emission technology coupled with a responsive, real-time processing capability has the potential to meet the requirement for this early detection.

PHASE I: Develop a method of collecting and identifying signatures characteristics of crack initiation and propagation for rotating gearbox components. Demonstrate feasibility of innovative algorithmic methods to isolate these signatures.

PHASE II: Develop a prototype acoustic emission crack detection system utilizing algorithmic methods. Validate the acoustic emission crack detection system in a demonstration to quantify capability and accuracy to detect crack initiation and propagation in rotating gearbox components.

PHASE III: Finalize the acoustic emission system health monitoring design with major DoD end users and airframe manufacturers and conduct qualification testing for the applications.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Robust health monitoring for noisy rotating machinery environments is very challenging and will provide great benefit for complex mission-critical machinery including aviation, transportation and industrial applications where early detection is key to ensuring safety of operation.

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KEYWORDS: Detection; acoustic; emission; crack; gearbox; damage

N12A-T008 TITLE: <u>Novel Temperature and Vibration Tolerant Packaging for Inertial Sensors (MEMS)</u>

TECHNOLOGY AREAS: Materials/Processes, Sensors

ACQUISITION PROGRAM: Common Laser Range Finder & FNC Azimuth Inertial Micro Electro Mechanical..

OBJECTIVE: Develop a cost-effective “generic” vacuum package which can accommodate a wide variety of micro- and milli- scale inertial sensors, increase robustness, and provide the sensor with temperature and vibration isolation from the environment. Vacuum packaging is critical to inertial sensors performance and determines the final sensor quality factor. The lower the vacuum, the better the quality factor (Q Factor). As a result, in this case the end product must be rugged and should maintain ultra low vacuum levels to achieve maximum accuracy. Note, increase Q factor results in a higher signal to noise ratio.

DESCRIPTION: MEMS based inertial sensors must reach extreme sensitivity levels in order to sense the Earth's rotation. As a result, any improvements in stabilizing the sensor environment (temperature, vibration, humidity) serve to improve sensor signal to noise ratio, thereby improving the final delivered accuracy. Additionally, by controlling the sensor environment, overall system design complexity is reduced, as feedback loops and other control schemes may be greatly simplified. Note, all MEMS based sensors require ultra low pressures to improve performance (reach maximum Q factor).

Leak rates and outgassing are the two factors which affect long term reliability of a typical vacuum packaged device. Assuming a device with a 2.5x2.5x0.1mm3 (0.625 mm3) cavity: for example, to maintain less then a 2 mTorr change in pressure in 1 day requires a <2e-14 cc/s leak rate and in 1 year it requires a <5e-17 cc/s leak rate. Typical He leak rate tests only have a resolution of approximately 1e-10cc/s. Given these assumptions, microscale packages need to have virtually no leak rate for long term reliability. The second factor, outgassing, involves the desorption of trapped process gases from inside the package. Due to the very small package volumes, desorption of fabrication process gases has been shown to be the dominant mechanism for increasing the pressure over time. In the development of long term and stable vacuum packages, it is important to characterize and eliminate both of these factors to produce a high quality packaged device.

PHASE I: Clearly identify micro- and milli- scale inertial sensors and their packaging needs with respect to temperature and vibration isolation and pressure. Provide a detailed package design and specify plans that can achieve and maintain extremely low vacuum levels (lower is better for Q factor) and to mitigate stress, vibration, shock and temperature effects from the environment. Identify military suppliers which may be used in this phase and provide a detailed price reduction strategy coupled to packaging innovations.

PHASE II: Utilize sensors for evaluating the package performance, demonstrating lowest vacuum level possible and robustness to outside temperature fluctuations and vibration. These can be sensors fabricated specifically for package evaluation or sensors provided by military or potential military suppliers. Given the stress, temperature and vibration sensitivity of the target sensor applications, this package should enable navigation grade performance.

PHASE III: Apply this technology and package to an inertial sensor from at least one supplier for military targeting and navigation applications for prototyping and pre-production runs. Provide a direct performance comparison of the environmentally robust packaging application developed to existing packaging technology and characterize all performance improvements.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: MEMS device isolation technology is needed to protect MEMS devices from temperature fluctuations, vibration and mechanical shock, as well as, maintain an ultra low vacuum level to maximize the Q factor (increase signal to noise ratio). Development of this technology may be used in any application (military / commercial) which requires improved accuracy or control of sensor environment to achieve a set of desired accuracy objectives.

REFERENCES:
1) MIL-STD-810F

2) Patent # 6,923,625 B2

3) D. R. Sparks, N. Najafi and S. Massoud-Ansari, "Chip-Level Vacuum Packaging of Micromachines Using Nanogetters," IEEE Transactions on Advanced Packaging, vol. 26, pp. 277-282, 2003.

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KEYWORDS: Low cost temperature and vibration tolerant packaging for inertial sensors

N12A-T009 TITLE: Development of Large Format Rapid Charge and Discharge Batteries for Underwater Warfare Applications

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes, Electronics

ACQUISITION PROGRAM: NAVSEA PMS399, Special Operation Forces Undersea Mobility; NAVSEA PMS406

OBJECTIVE: To conduct research of cell materials for the development of a large format, high-energy, rapid charge and discharge battery that is safe and reliable for underwater warfare applications.

DESCRIPTION: Batteries have become an essential component of a multitude of military and civilian applications. Batteries are generally designed for a specific component such as high energy density, high power, cycle life, calendar life, extreme temperature range etc. For most batteries that excel at specific component it does this as a trade off to other components. This solicitation's goal is to seek a battery that can successfully contain capacitor like power with battery like energy.

Successful completion of this topic will result in the development of a large format battery which will reduce mission turn-around time, increase Operational Availability and reduce total ownership costs to the Dry Combat Submersible program. In addition, a successful effort will yield benefits to a wide variety of military programs included the Electromagnet Rail Gun (EMRG), Large Scale Vehicles (LSV), and multiple Air and Ground Vehicles.

One key component that needs improvement is the charge/discharge rates. The Navy currently lacks the capability to quickly turnaround and redeploy a manned underwater vehicle by quickly recharging the battery. A battery technology that can reduce the charging time from hours to minutes while also providing good energy density and calendar life, under normal operational temperature ranges is desired. The battery should also have the ability to use high discharge rates when the situation is needed without greatly reducing the energy content of the battery.

Specifically, this solicitation requests the following characteristics for a battery that can be made modularly as needed from 1kWh to 1000's of kWh in size.
- >100C rate for both charge and discharge
- >100 Wh/kg at 100C
- >200 Wh/l at 100C
- >50 cycles at 100% depth of discharge
- Capable of operating in temperatures from -2°C to 45°C.
- Capable of being stored in temperatures from -20°C to 50°C.
- > 4 year shelf life

PHASE I: Provide an initial research and development effort that demonstrates innovative scientific and technical competency of the proposed high rate charge/discharge battery. The small business's role is to transition cell level material enhancements into viable cells. Conduct the preliminary testing to understand the fundamental properties of materials in the cell and begin to transition the technology from the lab to the commercial market. The research institution should focus on material research to enhance the fundamental properties of a cells ability to transfer electrons quickly at high rates during both charge and discharge. A combination of material enhancements (cathode, anode, electrolyte etc.) may be necessary to achieve the goals of this solicitation. The research institution and small business should work closely together to best evaluate the technology developments, plan future research and continue to improve performance of the materials and cells.

The key technology features should be demonstrated with small scale cells at a minimum of 2Ah (1C rate). The key parameters of this solicitation should be benchmarked (charge/discharge rate, energy density, specific energy, temperature, voltage, cycles, shelf life, etc.) and any major deficiency should have a plan remedy. Any additional safety concerns should be addressed, on both the small-scale and predicted large-scale Phase II plan.

PHASE II: Fabrication of large format, high energy, and high rate cells should be conducted and characterized. The small business and research institution should continue to evaluate the material enhancements of the cells and determine if the properties at small scale directly translate to larger scale. Continued research may be essential for the optimization of materials for both production and desired property adjustments. Initial tests should be conducted to validate performance and safety of the cells. Cells produced can be of any form factor but not less than 20Ah (1C rate), for evaluation. Cell geometry may include jelly roll, prismatic, pouch cell or other designs. Evaluation of these cells will be performed including validation of capacity, cycle life, thermal behavior and stability of operation at temperatures up to 50°C. A variety of abusive conditions in accordance with NAVSEAINST S9310-AQ-SAF-010 (or similar document depending on the battery type) should be conducted on the cells for the evaluation of safety.

PHASE III: Finalize development and transition technology to large scale production for Naval Underwater Warfare applications and other Navy, DoD or commercial products.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The successful development of a large format, high energy, rapid charge and discharge battery will be very beneficial to the private sector. One key area in which this kind of technology would excel is electric vehicles and hybrid vehicles industry. The ability to rapidly recharge the battery would allow for civilians to quickly recharge an empty battery providing the ability to drive longer distances then is currently accessible. Other possible commercial products include replacing the lead acid starter batteries for vehicles, increased power of electric hand tools, and replacement of capacitors in some applications. In addition to the increased mission capability for manned and unmanned underwater vehicles, the reduced battery recharge time while simultaneously increase the speed and pulse power applications would also be beneficial to multiple program offices including the electromagnetic rail gun (EMRG) program, Air and Ground Vehicles

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KEYWORDS: battery, high rate, cell, high energy, high power, charge, discharge

N12A-T010 TITLE: Developing and validating a model to understand mixed lubrication regions for fluid-film bearings

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: PMS 397 Ohio Replacement Program (ACAT I)

OBJECTIVE: This objective of this STTR is to develop and experimentally validate a model capable of simulating startup and shut-down of an elastohydrodynamic bearing.

DESCRIPTION: Innovative approaches are sought to model and simulate the startup and shut-down of an elastohydrodynamic (EHD) bearing. Inputs into the model should include critical film parameters during mixed and EHD lubrication transitions. Desired outcomes of this model are accurate torque and film thickness predictions throughout the mixed lubrication regime at which fully hydrodynamic conditions either occurs during startup or ceases during shutdown. The model must be experimentally validated.

Fluid-film bearings are used in several systems aboard ships. The improper design and usage of bearings can cause premature part and/or system failures leading to increased life cycle cost, decrease in mission capabilities and system availabilities. Hence, accurate understanding and modeling of these fluid-film layers are critical to the design, manufacturing, and maintainability of these bearing systems. Although fluid-film bearing modeling has advanced greatly over the past several decades and validated models for hydrodynamic and EHD regions have been demonstrated by several researchers [1,4], there is still a dearth of knowledge and validated modeling techniques to understand the operating regime between dry sliding and hydrodynamic/EHD conditions, called the mixed lubrication regime. The fluid characteristics in this region are constantly and rapidly changing, making it very difficult to understand and model. Furthermore, the focus for most of the current mixed lubrication research is on point [2, 3] and line [5] contact types (non-conformal contacts), rather than on conformal contact types, which is what bearings are and is the focus of this STTR.

PHASE I: Define and develop a concept model for the mixed lubrication region for rubber-lined bearings. Experimentally validate the concept model. Contractors may make use of public domain facilities operated by academic institutions.

PHASE II: After Phase 1 validation, further develop the model to enable combined hydrostatic, hydrodynamic, elastohydrodynamic, and mixed lubrication regions. Experimentally validate this expanded model.

PHASE III: Further develop the model to experimentally derived guidance for selection of critical film parameter for mixed-to-hydrodynamic lubrication transition. Continue to develop the model to commercially viable form or to a service provided for private sector and other government uses.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Fluid-film bearings are present in many systems, such as ships, aircrafts, automobiles, etc. A validated model for such bearings can benefit these industries during design, construction, and condition based maintenance.

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KEYWORDS: Fluid-film, bearing, elastohydrodynamic, mixed lubrication, hydrodynamic, model

N12A-T011 TITLE: High Resolution Measurement of the Coupled Velocity and Acceleration Fields of both the Fluid and Structure in Hydrodynamic Fluid Structure Interactions associated with Marine Vehicles

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: NAVSEA 073R, Advanced Submarine Systems Development (ASSD)

OBJECTIVE: Develop a low-cost, non-invasive approach to measure time-resolved fluid and structural velocity and acceleration fields that occur in a coupled fluid structure interaction associated with marine vehicles.

DESCRIPTION: Innovative non-invasive approaches are sought for simultaneous acquisition of the velocity and acceleration fields of both a fluid and solid undergoing a fully-coupled fluid-structure interaction. The coupled velocity and acceleration fields of a fluid and structure for a fluid around a moving structure are sought. Techniques which do not require the alternation of the structure to accommodate invasive sensors, such as optical techniques, are particular preferred (see references). Spatial resolution of measurement methods must also allow fine enough spatio-temporal resolution to capture large and small scale flow eddies near the solid surface, turbulent flow shear layer characteristics and structural response modes. Of particular importance is that the proposed method possesses sufficient time resolution to enable accurate measurement of the fluid and structure acceleration fields. The apparatus and technique should be capable of simultaneously characterizing the fluid and structure motions, be usable in large-scale test scenarios, capable of mounting to test vehicle, and should be capable of synchronization with other measurement acquisition. Any velocity/acceleration measurement method that meets the above requirements will be considered.

Modern composite structures are being designed to flex or deform under fluid loading to attain desired performance gains. The resulting fluid/structure interactions, not easily modeled by classical analytical approaches, have recently motivated development of advanced methods to simulate coupled flow and structural motion. The success of these advanced computational methods depends critically on high-quality, high-fidelity, validation measurements. In addition, once a full-scale device made from composite materials is built, its performance must be accurately characterized to ensure it meets design specifications. The accurate characterization of the fluid and structure acceleration field is also essential to accurate acoustic predictions.

The various commonly used velocity field measurement methods used to spatially map a flow field are either inadequate for coupled measurement of both the fluid and structural velocity and acceleration fields, or involve expensive, specialized high frame rate cameras and high firing rate lasers as an illumination source. For example, Particle Image Velocimetry (PIV) methods, can be extended to measure acceleration. For many users, the cost of a system capable of high-speed measurement is prohibitive due to the high cost of camera and laser. Often there is an inherent between illumination intensity and acquisition rate. This can be minimized in small-scale experimental setups, because the optical paths are short. However, it is desirable to allow high-speed acquisition in larger test rigs to accommodate larger-scale testing in a tow tank, flume, water tunnel, or in the field.

PHASE I: Define and develop a concept of an imaging method capable of simultaneous measurement of the velocity and acceleration fields of both the fluid and flexible structure undergoing coupled fluid-structure interaction. Evaluate the spatial and temporal resolution limits and identify approaches to improve resolution. Evaluate the velocity and acceleration measurement accuracy. Define the potential for development of low-cost version of the method. Address potential for on-board deployment in a test model. Contractor may make use of public domain flow facilities, such as wind and water tunnels operated by academic institutions.

PHASE II: Extend the Phase I methodology to improve any deficiencies, such as spatial or temporal resolution, and measurement uncertainty. Develop and deliver a prototype capable of meeting the objectives outlined above and capable of being used in large scale test facilities; such as tow tanks, flumes, water tunnels, or field trials. Improve upon the Phase I laboratory method to enable practical, low-cost version for future commercialization. Any differences between Phase I and Phase II methodologies are to be noted and explained.

PHASE III: Further develop the measurement method to commercially viable form, or to a service provided for private sector and other government uses.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The ability of current optical technology tools to characterize both the fluid and solid components of a fully-coupled fluid-structure interaction is limited by several factors. If successful, it is expected that this technology will provide excellent benefits for marine vehicle designers in both the commercial and military sectors and will be generally useful as a research and engineering tool. Significant benefits will be gained over a wide variety of marine and medical device applications. A large segment of these communities would be potential customers of this method. Finally, the emphasis on low cost solutions will encourage adoption by academic institutions as a teaching tool.

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KEYWORDS: Flow; Visualization; Velocimetry; Acceleration; Interaction; Hydroelasticity

N12A-T012 TITLE: Application of Auxetic Textiles to Military Protective Clothing

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: Program Manager - Infantry Combat Equipment

OBJECTIVE: Research and development of auxetic textiles for use in military protective clothing (e.g. body armor).

DESCRIPTION: Usually, when a textile is stretched, it becomes longer in the direction in which the load is applied, and narrower in the transverse direction. Auxetic textiles, however, become fatter when stretched and thinner when compressed, exhibiting negative Poisson's ratio. Several unique properties result from the "negative Poisson's ratio effect" including increased shear modulus, indentation resistance, fracture toughness, energy absorption, porosity/permeability variation with strain, and synclastic curvature. (Ref 1) Some of the proposed applications that could exploit these properties include helmets, body armor, gloves, padding and other types of protective clothing.

PHASE I: Provide an initial research and development effort that demonstrates scientific merit and capabilities of applying auxetic textiles to military protective clothing.

PHASE II: Laboratory scale specimens fabricated and their textile properties characterized.

PHASE III: Develop conceptual prototypes to demonstrate the suitability of the technology in a field evaluation.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: In addition to the military market, auxetic textiles might be applicable to protective clothing worn by the first responder community and athletes.

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KEYWORDS: Auxetic; textile; negative; poisson's; ratio; protective; clothing

N12A-T013 TITLE: Computing With Chaos

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Utilize the concept of nonlinear dynamical chaos to create a chaos-based computer for a novel approach to information processing that has the potential to be superior to existing technologies in finding optimal solutions for problem solving and decision-making. This research includes developing the software to program this chaos-based computer.

DESCRIPTION: Nonlinear dynamics has revealed a rich array of behaviors, especially those related to chaos including routes to chaos, high and low dimensional chaotic attractors, crises, transient chaos, and Hamiltonian strange kinetics. In neural systems, measured phenomena includes chaos, synchrony, and cascading avalanches demonstrating that information processing in the brain is not just anatomical, but also dynamical. This program seeks to take advantage of the richness of nonlinear dynamical systems and insights from neural systems to devise new approaches to computation. Possible approaches include utilizing computing with attractors, transient chaos in high dimensional systems, chaos controlled reconfigurable logic gates, and pattern formation. Cues may be taken from neuroscience with network topologies of excitatory and inhibitory connections and plasticity of learning through strengthening of connections at synapses. We seek a “plastic” computational network that can be programmed to adjust rapidly without a physical rewiring to seek optimal solutions to problems. The sought after approach is to include nonlinear dynamical behaviors into an information processing system that can optimize solutions to complex problems. This research promises a revolution in information processing for areas such as pattern recognition where a complex circuit can self-organize by morphing between logic gate configurations to search for specific patterns, such as, faces, or vehicles. The incorporation of concepts from neural cognitive behavior can led to feedback and self-organization designs to increase the effectiveness of information processing. Novel computing can allow for a versatile response to information flow which can lead to new paradigms for the optimization of solving complex problems, such as the control of robots and other autonomous systems.

PHASE I: Design a computational system that is based on the nonlinear dynamical principles of chaos that can perform all logical operations. Provide a feedback mechanism that can allow the system to self-organize its logic to optimize solutions to tasks.

PHASE II: Further develop the computation system from Phase I to maximize its computational speed and minimize the number of logic gates and wiring connections to reduce cooling requirements. Build the computational system on a chip and demonstrate its ability to find optimal solutions to a complex task.

PHASE III: Build nonlinear dynamical computers with self-organizing logic to optimize solutions to tasks, such as, controllers for autonomous systems, including robots and vehicles. This includes developing a programming language for general computational problems.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: A reconfigurable chaos-based computer will be of value to military and civilian customers. Reuse of logic gates whose logic is morphable can led to the need for fewer logic gates. This will decrease wiring requirements and lower heat production. This alone will be a strong positive factor for industry as it will lower cooling requirements. The chaos-based computer will offer new approaches to problems in pattern recognition, voice recognition, and controller for autonomous vehicles and robotic platforms.

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KEYWORDS: chaos; nonlinear dynamics; computation; logic gates; reconfigurable; self-organization

N12A-T014 TITLE: Multi-Chip Module Maturation, Whole Wafer testing, and Reworkable Epoxy Bonding

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

ACQUISITION PROGRAM: Silk Thread FNC (FY13 start), IARPA Cyrogenic Memory Program (FY12 start)

OBJECTIVE: The objective of this work is to develop the initial ability to test the functionality automatically of all the die on a wafer before it is diced to find the working die and then to mount the "known-good" die into a larger circuit in such a way that repair to the functionality of the whole can be accomplished by replacing the part, not the whole. Such shrinkage of the line replaceable units will make the costs of building complex system functionality in immature digital technologies more affordable. Substantial innovation on packaging technology is required to deliver success on this topic as reworkable cryogenic epoxies are unknown and automated testing protocols at the expected 10's of GHz clock speeds are very immature, even at room temperature. Existing 6 probe RF commercial testing stations that can deliver signals at the clock frequency currently heat the active device to >6K, unacceptable for the required <4.5K 200 probe testing.

DESCRIPTION: When a digital device technology is immature, as is the case today for both the advanced semiconductors and the superconductors, it is desirable to be able to assemble a complex circuit out of smaller die that have been individually tested and are known before assembly to be fully operational. These “known good die” must therefore be tested without permanently attaching them to a test circuit. Instead a method of bonding that can be reversed without subjecting the die to a too elevated temperature or chemical components that can degrade the circuit functionality must be located. Reworkable epoxy that can be etched away in a process similar to that used for MEMs sacrificial layers may be a good method of achieving that goal. Moreover, it is desirable to have a method of doing automated testing of stepper reticle areas and eventually whole wafers of the die. Having such a technique eliminates the costs of technician time dicing and packaging non-functional die, while the number of die actually tested increases, thereby facilitating statistical process control. The proposal should state the planned approach to accomplishing both these goals and the expected division of labor between bonding and testing subefforts.

PHASE I: Focus on the superconducting case which sets a maximum processing temperature for both assembly and disassembly of 125C and establishes the exposed materials as fine grained Nb, its oxides, Al, Mo, amorphous Al_2O_3, SiO_2 and Si_3N_4 and the substrate as Si coated with SiO_2. Demonstrate as a proof of concept that a reworkable epoxy (or alternative bonding method) can produce low electrical resistance bonds which are mechanically robust under ultrasonic vibration as set, withstand thermal cycling to 4K, and can be fully removed when processed to release. Ideally the bonding method will also help remove heat from the face of the active die at 4K. Elaborate method of extending the approach from single die to arrays of such die on a reticle area/full wafer. Alternatively, elaborate a method of performing at speed (>20 GHz) and temperature (<4.5K) testing of repeated die structures on common substrate and define how reconfigurable wiring connections to room temperature signal and current generators will be accomplished.

PHASE II: Iterate the bonding method, develop and demonstrate the whole wafer bonding concept, and culminate work with a demonstration of both a 4 die MCM manufacture and successful automated test at clock speeds above 20 GHz of at least 2 different die while still in whole wafer/reticle form.

PHASE III: Become the bonding method of choice for the digital and mixed signal low temperature device community.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The government supercomputer market is less than 5% of the whole market for such machines; multiple user base stations renting

BW may be a viable business model. Thus the applicability of this effort to these 2 that the technology developed will have dual use applications.

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KEYWORDS: multi-chip module construction; reworkable epoxies; whole wafer testing; high speed circuit testing; packaging; die scale heat removal technologies

N12A-T015 TITLE: Energy Efficient HF Transmit Antennas

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

ACQUISITION PROGRAM: Program Executive Office for Integrated Warfare Systems

OBJECTIVE: Current HF antennas are resonant and single function. Given the 10 to 1000's of meters of wavelengths at these frequencies, the antennas thus add substantial weight, radar cross section, and thermal signature to the platforms that carry them even as they cover a very narrow spectral range. Most man-pack scale platforms thus omit their functionality. Several approaches (superconducting SQIF, metamaterials, and plasmmonics) are attempting to build electrically small HF receive antennas, but their functionality in transmit mode appears more limited. The idea of this topic is to accept the idea that Tx requires substantial area and try to include the radiation function with some other function. For example, combine HF Tx with solar collectors (also produce power used), hull plates,walls and roof tops and armor. Moreover, there is the appealing idea of distributed production of RF energy of directional beams at the intended frequency. This could be done via strongly sub-wavelength phase arrays (ala a Hyugens wavelets construction of the interference pattern of multiple slits). Another idea which could be explored under this topic is that of sparse arrays in 3D of such arrays. Finally thermoelectric energy harvesting off hot amplifiers could both lower thermal signatures and improve energy efficiency.

DESCRIPTION: The military is as desirous of reducing the weight, size and power consumption of military platforms as is the consumer electronics world since large SWaP impedes mobility and raises maneuvering costs. However, some wireless frequency bands such as HF have such long wavelengths (300m at 1 MHz) that transmitting it efficiently off any platform smaller than a 747 plane is difficult. Thus it is desirable to figure out how to utilize another, more essential and not necessarily planar part of the platform to do double duty as an energy efficient HF antenna, possibly using optical phased array techniques to coordinate multiple discrete non-resonant transmission elements into producing quasi-plane waves in the far field. Proposals for phase 1 need to present a definite design concept to be worked with a specific class of platform in mind, not propose to do a paper study of several approaches that could be considered. A concept of antennas that facilitate energy efficiency via co-utilization by multiple functions, optimal placement, use of untapped energy sources and energy and area effective design is to be reflected in the proposal.

PHASE I: This phase should elaborate and refine the design concept defined in the proposal. If the approach requires layering, e.g. of photo-voltaics with antenna elements or antennas in structural members, issues of shadowing/field distortion and strength of the composite should be assessed. Small experimental efforts might be tried if the required parts have a short lead time. Furthermore, directionality must be considered to leverage gain to mitigate the power requirement. Arrays should be considered for optimal location and creating a real estate trade space. Multiple functionally needs to be addressed for receive, transmit, and geolocation, simultaneously. Design concepts that could be utilized for expendable, off board antennas would be acceptable as would antennas suitable only for naval combatants. Critical performance parameters include radiation patterns, gain and power handling for the antenna and power produced and cost efficiency for the alternate energy sources. By the end of phase 1 base, a clear image should have formed for the phase 2 proof of concept demonstration and the technical risk of the approach be strongly reduced.

PHASE II: Execute the proof of concept developed in phase 1 first at small scale in a lab and then, after iterating the design, on an antenna range or in an anechoic chamber using a representative example of the platforms of interest. This prototype phase might be included, if suitable, a fleet experiment and exercise.

PHASE III: Transition to a program responsible for the focused on platform demonstrating its increased performance would be expected. Production of an advanced prototype, further integration and limited production is anticipated.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: While HF is decreasingly of interest to the wireless community due to its lack of locality and congestion, the dual functionality approaches to antennas developed here should also be applicable in shrinking higher frequency systems. For example, having the antenna for a cell phone be spread over the entire package will help increase the antenna gain and lengthen battery life, especially if the power distribution is adaptive and thus turns off segments under the human's supporting hand.

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KEYWORDS: non-resonant antennas; HF antennas; plasmonics; multi-functional materials; layered packaging; optical phased arrays

N12A-T016 TITLE: Long-Range Arctic Undersea Navigation for unmanned systems

TECHNOLOGY AREAS: Ground/Sea Vehicles, Sensors, Battlespace

ACQUISITION PROGRAM: This STTR will support code 32 D&I in unmanned vehicles.

OBJECTIVE: Due to reductions in ice cover, there is an increased focus on the potential for future operations in the Arctic region. This environment is a challenging and dangerous one in which to operate, which provides a strong incentive for autonomous platforms. However, an Arctic navigation capability for UUVs is problematic, as ice cover may hinder the ability to surface and gain a GPS fix, and the availability of GPS at high latitudes is severely limited as well. For underwater and under-ice operations, an opportunity exists to use acoustics to provide an in-water navigation capability. Such a navigation system could represent a dual-use capability by not only providing the necessary signals for triangulation, but the signals could be used for environmental sensing of the ocean (traditional tomography) as well as ice cover (via scattering statistics).

DESCRIPTION: Due coverage by sea ice, UUVs will not reliably be able to periodically surface to obtain the high accuracy GPS fixes required to maintain accuracy in their navigation systems. Current navigation systems degrade over time, minimizing the reach of unmanned undersea systems to near the edges of the Arctic ice. Current transponder system are short range and require multiple systems to be installed which can add significant cost and time to setup and install on the ice surface.

The goal of this effort is to develop technologies to enable a basin-scale under-ice navigation system that would allow for high accuracy navigation of UUV under the ice. From current research, new technologies are needed for this system to work. This SBIR will accept system proposal or critical technology proposals. The following are considered critical technology

Low-power low-frequency transducers: To achieve the acoustic ranges necessary to reach across the Arctic basin, the acoustic sources must operate at low or very low frequencies (5-100Hz) in order to avoid the multiple scattering that will diminish propagation distances. They must also be relatively low-power and low-cost, as they may be moored in the deep ocean or integrated onto a UUV. New transducers are needed to reduce the power to 10 watts in operation, be neutrally buoyant, and be no larger than 3” in diameter and 8” in length to enable integration onto a UUV.

Signal processing: The Arctic has a different acoustic environment with multi- path propagation due to the reflection on the bottom and off the ice. New navigation algorithms are needed to properly account for this specialized environment and resolve accuracies to within a few meters with an objective of one meter.

Methods for receiving GPS or other signals through the ice: This may include design of ice hardened antennas that can cut through the ice or new antenna designs and algorithms that can detect GPS or other signals through sea ice cover.

PHASE I: Develop a preliminary design for the system or critical components. Provide the theoretical predictions of the system and develop a technology development plan for Phase II. The deliverable should be a preliminary design of the system. If the design or components of the design are high risk, a risk reduction plan should be included

PHASE II: Complete the system design. This task should include any risk reduction tests, detailed design review, and test plan. Fabricate two prototype system or technology components and complete laboratory and development tests. Support government integration of the proposed system onto ONR UUVs. Support at sea tests of the prototypes on a government UUVs.

PHASE III: The proposed system will be integrated into current navy oceanographic sensing systems. The technology will be integrated on board both S&T and Acquisition unmanned vehicles and used in oceanographic sensing mission in the arctic.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: There is significant interest in Arctic operations and logistics from the science community and commercial industry. There is significant interest from international partners in Arctic research which could utilize this technology to advance scientific research in the Arctic.

Private industry is very interested in Arctic sensing technology development, as the Arctic may contain a vast amount of untapped natural resources. The oil and gas industry continues to gather as much information on this area as possible to plan for future oil drilling operations.

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KEYWORDS: Unmanned Undersea Vehicles, UUV, Navigation, Arctic

N12A-T017 TITLE: Expendable Acoustic Source for AUV Based Geoacoustic and Geotechnical Survey Operations

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: Littoral Battlespace Sensing - Unmanned Undersea Vehicles (LBS-UUV) ACAT IV

OBJECTIVE: Provide future Naval Oceanographic Office survey teams with expendable calibrated sources for use in determining the bottom sediment acoustic properties necessary for planning and operation of low and mid frequency ASW sonars in shallow water. Further, the inversion of the acoustic information for geotechnical properties will support classification for mine burial prediction.

DESCRIPTION: Acoustic sources on the bottom are advantageous for bottom acoustics surveying, as: 1) there is less spreading loss to reach the medium and 2) within a few meters of the bottom, a pressure source can excite Scholte waves, which can provide information about bottom shear properties. When coupled with a near bottom receiver (like a terrain hugging AUV), such a source/ receiver configuration sees the Scholte wave. Absent such a source, AUV based surveys must rely on sources of opportunity like passing ships, which are band limited, surface wave noise, which is inherently high angle, or an AUV based source on a separate vehicle which has the same endurance as the receiver vehicle. One time use sources (sonabuoys) are frequently used in Maritime Patrol Aircraft ASW efforts. They can also be found in the form of acoustic countermeasures employed by submarines for evasion and escape, but the application to bottom survey would be novel.

PHASE I: Design and demonstrate through simulation or limited testing the potential to develop a 0.1 - 4 kHz coherent source that is low cost and has the potential to operate at depths down to 100 meters for up to two hours prior to scuttling.

PHASE II: Demonstrate a prototype source in a realistic environment. This phase will include development of hardware. A completely functional prototype is not required; however, the feasibility and the expected performance of a final design should be clearly evident within the demonstration.

PHASE III: A low cost prototype 0.2 - 4 kHz coherent source system that has the potential to transition into the LBS-UUV POR.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: A dual use application could be basic and applied research related to Geoacoustic and Geotechnical Inversion and Survey technique development.

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KEYWORDS: unmanned undersea vehicles; littoral; acoustics; sources; inversion; survey

N12A-T018 TITLE: Toolset for the Robust Design of Materials for Superplastic Forming Processes for Titanium Structural Components

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

OBJECTIVE: The objective of this project is to provide a suite of tools to model the sequence of unit operations, and materials response, in the processing of titanium alloy plate or sheet from primary ingot and/or sponge form. This would allow the primary metals suppliers to design robust processing sequences, trouble-shoot process problems, and refine processes to reduce costs without sacrificing materials quality. This project supports the goals of the Materials Genome Initiative (MGI) in the area of Integrated Computational Materials Engineering (ICME).

DESCRIPTION: Superplastic Forming (SPF) is a well-established process for solid crystalline materials, such as titanium. In the superplastic condition, the flow stress of the material is low and the ductility is extremely high. Forming under these conditions allows for the production of large, very complex shapes. This allows for piece-part consolidation -- eliminating the need for multiple sub-parts, bolts that increases inventory, labor, and cost. It also produces a uniform final microstructure, which results in uniform properties with improved performance and reliability. The aerospace and automotive industries use this process to manufacture very complex geometries. It is most beneficial for these industries because it is critical to reduce the weight in order to achieve higher speed or fuel efficiency. Specific applications include aircraft frames and skins; window and doorframes, floor structures, and dashboards; and propulsion and ducting systems.

Historically, there have been several challenges to using superplastic forming in production. One major challenge is the need for very consistent uniform microstructure and properties in the starting sheet or plate. In addition to lot-to-lot variation in materials, end-to-end variations in sheet properties may lead to defects and failures during superplastic forming. This could lead ultimately to high scrap rates, unacceptably high overall costs, and reduced part reliability.

Material variability from a primary metals supplier stems from multiple causes, including melt-related and wrought-processing-related defects. The former include the presence of iron and other transition metals in the sponge, and high oxygen content from the melting processes. These can lead to macrosegregation in solidified ingots that subsequent remelting may not mitigate. Wrought processing, from ingot to billet to plate, and from plate to sheet, involves a number of unit operations. Mill suppliers also have a strong incentive to reduce the overall costs of their operations. They can accomplish this by reducing the number of processing steps, increasing product yield, et cetera. Any process modification, however, may affect final microstructure and subsequent superplastic properties and require careful consideration.

We have good understanding of the physical processes for each of the operations, but not necessarily detailed models for material behavior and microstructure evolution during processing. This is the case especially for two-phase materials, such as the alpha-beta titanium alloys like Ti-64. Hence, models for these phenomena may not be fully adequate at present for process optimization and troubleshooting processing problems. In addition, the superplastic forming process involves several physical phenomena to allow large deformations without large net changes in the microstructure of the sheet. This does not mean that the microstructure is static, but that the microstructure evolves with deformation to maintain a stable state. Various metrics in microstructure are important in this. For the single-phase materials, a fine uniform equiaxed structure is desirable. For a two-phase material, the average grain size may not be the most appropriate microstructure metric, but some other measure such as the phase-boundary area, et cetera. It is important that modelling of the processes to produce input materials for superplastic forming also incorporate models for the superplastic forming process, in order to allow for optimization of the entire production operation from start to finish.

PHASE I: In the phase I effort, the investigators should focus on the plate-to-sheet thermomechanical processing sequence to make superplastic sheet of a common commercial two-phase titanium such as Ti-64. These steps should include characterization of the starting condition/microstructure of the plate, preheating of the plate, the rolling operation(s), and intermediate/final heating/heat treatment steps. The investigators will show the ability to model each processing step using existing or new models and software to predict optimal processing parameters for the rolling/heating operations, and to track material history along the length of a sheet through all of the unit operations. The investigators need to define deficiencies in current physics-based understanding, and associated models, of microstructure evolution as well as the R&D required to alleviate such deficiencies. Full success in this phase will produce a protocol for tracking materials history across the processing operations, with a preliminary toolset for the optimization of the plate-to-sheet process.

PHASE II: In the phase II effort, the investigators should complete the models for plate-to-sheet processing, to allow prediction of microstructure evolution and subsequent superplastic forming properties such as the constitutive behavior of the material as a function of the chosen processing steps and process variables. The team should pay particular attention quantifying variability in microstructure and constitutive response within a sheet and from sheet to sheet as result of the nature of the material synthesis operations and TMP steps. The investigators must verify and validate the applicability of the plate-to-sheet material behavior and process models by working with a primary metals supplier to model a typical production-scale process. They should also work with metal fabricators that use superplastic forming to ensure that the sheet properties are appropriate for the forming operations and useful to the customer shops. Finally, the models need to be useful for other alloy systems than the target for this project.

PHASE III: The immediate application of the toolset is to primary metals suppliers. The investigators should connect with the various metals suppliers to provide either support services for process optimization, to sell the tool-sets to allow the suppliers to perform in-house optimizations.

The investigators will need to define and assess the state-of-the art of models for the ingot-to-plate processes using the techniques that they developed for the plate-to-sheet models as appropriate. They should begin to model microstructure and properties throughout the plate as a function of ingot starting conditions and processing parameters in the multi-step process. They will also need to provide integration with existing ingot solidification models. Finally, with the current low-cost titanium efforts focused on powder production, the investigators will likely find it useful to explore the modelling of the direct consolidation of powder into plate product and possibly direct plate casting.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: This toolset will allow the metals suppliers to optimize their plate and sheet processing operations for any applications, including for the oil and chemical industries where titanium is important for corrosion-resistant applications. The material-behavior and process models, and the protocols for retaining material history, should be relatively materials agnostic. This is of considerable interest to the aerospace and automotive industries.

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KEYWORDS: titanium; superplastic forming; process modelling; process optimization; ICME; MGI

N12A-T019 TITLE: Affordable CMAS -Resistant Thermal Barrier Coatings

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

OBJECTIVE: Develop strategies and viable, affordable production methods for CMAS-resistant thermal barrier coatings (TBCs) for turbine engine components prone to such attack. This should include the creation and development of a computational code that describes processing to create relevant structures or chemical or thermo-mechanical-based structure/property relationships relevant to CMAS resistance that could be incorporated into a larger, multi-code integrated computational materials engineering (ICME) processing protocol. In Phase I, several strategies will be considered, matured and downselected. Maturation will include cost and demonstration of small-scale production and scalability of competing technologies with a downselect of the optimal technology.

DESCRIPTION: The remarkable increase in efficiency of gas turbine engines over the last 60 years has been achieved in significant measure by elevation of the engine gas operating temperature. This was enabled by (i) the development of superalloys that were increasingly resistant to creep, hot corrosion and oxidation, (ii) the invention of novel blade cooling techniques integrated into single crystal airfoil fabrication processes and (iii) the emergence of oxidation and hot corrosion resistant metallic bond coats and TBCs that reduced their temperature. Improved TBC systems for hot section air foils are of critical importance as the turbine inlet gas temperatures continue to rise [1]. For example, increases in the combustion chamber and turbine inlet temperatures of military gas turbine engines have resulted in the melting of dust particles upon contact with hot components with potential catastrophic consequences. These calcium aluminum magnesium silicate (CMAS) dust and volcanic ash particles melt on the surface of the thermal barrier coatings applied to these components. The coatings are then susceptible to dissolution and reaction with these liquid deposits. The resulting liquid glasses are able to wet the surface and internal interconnected pores within the coatings enabling their rapid penetration and dissolution of the protective coating. Upon cooling, the glass and reaction product phases solidify and the void structure that is utilized to reduce thermal conductivity and provide the strain compliance are lost leading to delamination of the affected region of the coating. Rare earth zirconates have been found to provide resistance to CMAS attack, but are unstable with thermally grown alumina TGO layer which requires yttria-stabilized zirconia to be applied adding to the complexity and cost. The zirconates are also less resistance erosion and foreign object damage.

This topic seeks proposals that investigate novel concepts for mitigating the effects of CMAS upon current and future thermal barrier coating systems. Proposals are sought that (i) identify promising mitigation concepts, (ii) develop the ability to synthesize coatings and (iii) demonstrate that CMAS mitigation can be achieved without degradation to other essential coating properties (especially high through thickness thermal resistance, thermo-mechanical life, erosion and impact damage resistance).

PHASE I: A number of promising strategies for the mitigation of CMAS effects will be investigated including the use of coating compositions that are not as readily wetted by CMAS, the use of compositions that promote precipitation of high melting temperature reaction phases that impede the penetration of the liquid glass, compositions that increase the viscosity or melting temperature of the glass upon reaction within the coatings, and the use of multi-layered coating architectures including those that contain layers with reduced interconnected pore fractions (dense layers) or utilize non reactive metallic layers to impede CMAS penetration. Maturation will include showing the feasibility to demonstrate small-scale laboratory production (actual demonstration to be done in Phase II) and the production scalability of competing technologies and demonstrate a CMAS-resistant TBC with a downselect of the optimal, affordable technology. A framework for creating an ICME code for specific processing-structure or structure-property relationship needs to be demonstrated. Interactions with turbine engine OEMs (original equipment manufacturers) is strongly encouraged.

PHASE II: Develop a detailed test plan to scale-up processes for TBC production from a laboratory size to an industrial size. Demonstrate a small-scale laboratory production of the CMAS-resistant TBCs and assess the consistency of materials properties. Conduct material property tests at the level required to provide data for the design of a suitable component for demonstration in an OEM or DoD core engine test. The ICME method chosen in Phase I needs to be matured and validated. Provide material for manufacture and test of the suitable component.

PHASE III: Transition the material production methodology to a suitable industrial material producer. The ICME code needs to transitioned to the commercial entity for potential incorporation of a more comprehensive ICME code. Commercialize the material for use in DoD and commercial markets.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Commercial Aviation industry would benefit from this technology when flying the sand-ingested areas such as the Middle East. and would provide some added protection for aircraft against the effects of volcanic ash as there are similarities chemically with CMAS and volcanic ash.

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KEYWORDS: CMAS; TBCs; thermal barrier coatings; calcium-magnesium alumino-silicate; turbine engine corrosion, coating delamination; CMAS-resistant coatings

N12A-T020 TITLE: Dive Helmet Noise Quieting

TECHNOLOGY AREAS: Materials/Processes, Battlespace, Human Systems

ACQUISITION PROGRAM: NAVSEA 00C3 Diving Programs

OBJECTIVE: Create technologies to reduce the acoustic noise produced by, and transmitted through, dive helmets.

DESCRIPTION: Helmeted divers are exposed to high levels of noise. The sources of these noises can be self-generated [1] (e.g., airflow through the demand-regulators during inhalation and bubble noise during exhalation), as well as transmitted through the helmet from underwater tools [2]. While administrative controls (i.e., noise exposure guidance and regulations) are a necessary part of an overall hearing protection strategy, the critical component that determines success depends on our ability to eliminate the effects of various noise sources [3,4].

PHASE I: Determine the feasibility of developing and constructing technologies to reduce the acoustic noise produced by and transmitted through dive helmets (<84 dBA), with appropriate consideration for optimizing the diver's communication needs. Develop a detailed design of system(s) that will address the noises associated with the various dive helmets currently in use by the U.S. Navy. If deemed necessary, new dive helmet designs will also be considered.

PHASE II: Construct physical prototype(s) of the diver helmet noise reduction system. Characterize the system's acoustic quieting performance. Test the system for operational safety. Produce two final prototypes for testing at the Naval Submarine Medical Research Laboratory (NSMRL) and Navy Experimental Diving Unit (NEDU).

PHASE III: Construct production units suitable for certification for the Approved for Navy Use (ANU) List and develop marketing plans for a broad range of customers.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: National and international underwater construction firms and ship's husbandry companies would clearly benefit from this technology. Respondents should explore these potential markets and seek partnerships with current dive helmet manufacturing companies.

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KEYWORDS: diving; hearing conservation; acoustic noise; underwater noise; noise control

N12A-T021 TITLE: Imaging through low-visibility fire smoke for ship-board navigation of robotic fire-fighting systems

TECHNOLOGY AREAS: Ground/Sea Vehicles, Sensors

ACQUISITION PROGRAM: PEO(S) Program Executive Office for Ships, Director for S&T

OBJECTIVE: Identify sensing modalites, sensors and image processing that can image through smoke (where visibility of a light reflecting object is less than 1 ft). This sensing and imaging system must be compact enough to be incorporated into future shipboard robotic firefighting systems, and enable navigation by revealing surfaces, doorways and obstacles.

DESCRIPTION: Fire suppression onboard a ship is one of the most dangerous jobs that sailors may need to perform. In addition, firefighting requires numerous sailors to conduct taking the crew away from performing other tasks on the ship. To help reduce the hazards associated with fighting fires onboard ships, the Navy is developing new robotic systems for fighting fires. One of the challenges in developing these new systems is having sensors that are capable of seeing through the low visibility smoke which may develop during a fire. To support firefighting activities, a sensing and imaging device is needed to locate the boundaries of the ship, equipment and furnishings within the space and other obstructions. Fire conditions may evolve quickly; therefore, this device must be able to scan the space to locate surfaces in a short period of time to support the firefighting systems. Smoke strongly attenuates visible light, and also significantly impedes the function of LADAR imaging. Thermal inhomogeneities and turbulence also confound imaging in fire conditions. There are however some promising detection, ranging and imaging methodologies that may include near IR, mid IR, millimeter wave imaging, synthetic aperture radar (SAR) and/or active ultrasound technology (or some combination thereof) that will need to be further explored to enable future autonomous robotic firefighting operations within the confines of a shipboard environment. A combination of far field (eg. wall, door opening, obstacle detection & mapping) and near field (navigation through narrow openings) sensing may be necessary.

PHASE I: Identify the most promising sensing mode, spectral regions and imaging approach for imaging surfaces, boundaries and objects, including casualties, through smoke. Identify a sensor or sensor array that could be mounted on a human sized robot and develop imaging approaches to support navigation and obstacle avoidance, as well as fire location. A nominal guideline is that the proposed sensing and imaging device be able to locate reflecting surfaces from 15 ft away through smoke with a visibility of less than 1 ft as determined through relationships developed by Jin [1]. The design study should estimate the speed at such a system can locate the boundary and highlight the method by which the device will be able to scan the obstructions and boundaries inside a compartment. Devices must also be capable of accounting for elevated temperature gases produced by the fire and its affect on boundary location. Estimates of the cost, performance, size and power of such a system should be made.

PHASE II: Develop a prototype system and demonstrate that it is capable of locating boundaries and obstructions in scenarios containing smoke from a real fire. The device should be able to locate boundaries and obstructions, nominally 15 ft away within 1 second. Develop a system for navigation of a mobile robot based on the sensor imagery. Design a compact, lightweight version of this system.

PHASE III: Contractors shall work with the Navy and their contractors to implement the device developed in this program into advanced firefighting systems. In addition, the contractor shall identify commercial vendors that may transition this technology into the commercial sector to support public firefighters in navigating through low visibility smoke environments in building fires.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: This system would be applicable to public firefighters working in low visibility smoke environments in building fires and first responders seeking casualties and evacuation routes in disasters involving smoke or other obscurants, and this technology would provide substantive commercial opportunities.

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KEYWORDS: Smoke, imaging sensors, ultrasound, millimeter wave, firefighting, robotics, navigation

N12A-T022 TITLE: Intermediate Transient Support of High Rate and Pulsed Loads

TECHNOLOGY AREAS: Information Systems, Electronics, Weapons

ACQUISITION PROGRAM: Office of Naval Research Code 352: Railgun Innovative Naval Prototype (INP)

OBJECTIVE: To develop a power system that can support intermittent pulsed power loads by providing consistent load to the generation source during pulsed power duty cycle.

DESCRIPTION: Navy ships can be thought of as having an electrical microgrid to distribute power. Conventional plant designs have separate mechanical propulsion and weapons systems with the electrical plant to support hotel and combat systems. Future all electric naval ships will require prime movers to all have the functionality of distributed electrical generators, to power a wide variety of loads ranging from conventional electronics, electric propulsion systems, and even pulsed power systems that will drive electric weaponry. The pulsed power systems will draw power from the ship's electrical distribution to enable continuous operation, and while large-scale energy storage may support operations, high rate intermittent storage is necessary to ensure that the electrical distribution and prime movers are provided with relatively consistent loading. During the charge process of the pulsed power system, a considerable amount of power will be drawn from the electrical grid for time durations on the order of seconds, with a lapse in between charges. The large power draw in an intermittent fashion is difficult to control and difficult for non-stiff electrical generators to supply. Enabling technologies that support a supplemental high rate storage system is required that enable pulsed power loads to be effectively used on board the ship without disruption to the other loads or damage to the distributed generators.

Innovative R&D is needed to model and validate novel high rate, intermittent energy storage and control architectures that can rapidly accept high intermittent currents to load-level prime movers during the pulsed-power duty cycle. The architecture should be designed to minimize the impact this type of operation has on the electrical generators and support the pulsed load modules' operation. The energy storage must be able to accept rapid charge from the generation system within the constraints of the duty cycle of the pulsed power system, and then provide this stored energy on the order of seconds to allow for cyclic capability in a continuous manner. New high peak power energy storage technologies and designs are needed to accomplish this goal. Control system architectures and algorithms must also be developed to ensure load leveling in all modes of operations while ensuring safety and constant operation. These devices, with the requisite conversion schemes are necessary in highly dense packages to allow for implementation in volumetrically constrained environments. Proof of principle hardware tests and validated computer design models are desired.

Full scale pulsed power requirement:
- Pulsed power duty cycle: >80%
- Power accept example: 1 sec in a 6 sec cycle
- Energy storage power level: Modular 1MW approach
- Energy storage of >3 MJ per module
- Energy storage charge rate of >1MW
- Energy storage power delivery of >500 kW
- Energy Storage interface voltage 1000V

The Navy will only fund proposals that are innovative address R&D and involve technical risk.

PHASE I: The offeror will conceptualize an intermediate storage approach that utilizes advanced high rate components to be able to continuously accept and provide power to operate on a load leveling basis. Small scale, proof of concept experimentation can be performed to demonstrate hardware's ability to drive high peak powers with a compact and sensible architecture and package. Control algorithms that maintain load leveling should be developed and demonstrated on small scale hardware systems.

PHASE II: The conceptual architecture and controls will be demonstrated at a relevant scale which aligns to the requirements as provided within this solicitation for voltage and rates. Modes of continuous operation will be shown without degradation of the device, and will support operations under elevated temperature regimes up to 140F. Cooling and other interfaces shall be specified and demonstrated for performance.

Phase IIa Option: The offeror will build additional intermediate storage devices and expose them to a variety of pulsed power system concepts as well as abusive conditions.

Phase IIb Option: The offeror will cycle the modules for extended periods to fully characterize degradation and capacity loss with use under relevant conditions.

PHASE III: The offeror will apply the knowledge gained in phase II to build a multiple-MW scale system to support intermediate storage operations. The system will be able to provide load leveling performance as defined within the solicitation and will be demonstrated as such.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: High rate charge/discharge applications including fast-dispatch frequency regulation, large power system load leveling and scheduling, microgrid applications.

REFERENCES:
1. B. Shrestha, D. Wetz, P. Novak, G. Sarkar, J. Kelley, J. Reed. 'Discharge of Electrochemical Energy Storage Devices at Elevated Rates for Driving Pulsed Power Applications'. 18th IEEE International Pulsed Power Conference, Chicago, Illinois, June 19-23, 2011.

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http://www.onr.navy.mil/~/media/Files/Fact%20Sheets/Next%20Generation%20Integrated%20Power%20Supply.ashx

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KEYWORDS: energy storage; high-rate; power; energy

N12A-T023 TITLE: Coupled Molecular Design and Synthesis of High Density Energetic Materials

TECHNOLOGY AREAS: Materials/Processes, Weapons

OBJECTIVE: This effort will exploit the use of theoretical molecular design, organic synthesis manipulation, and quantum chemical modeling to provide energetic materials which meet existing munitions performance while achieving IM compliance. The investigator will establish and verify the molecular design, the form and nature of the crystalline packing and the interactions with matrix materials in a composite system. Scientifically, this program will establish the foundation upon which the molecular design, the nature of crystal packing and the interactions with matrix materials in composite systems are combined to design energetic ingredients resistant to thermal or shock loading conditions. The program will provide a potential replacement of one or more of today's energetic ingredients solving the requirement for an insensitive high performance energetic material for combat safe military applications.

DESCRIPTION: This program will team molecular dynamics and organic synthesis chemists, materials scientists and theoreticians. While the fundamental challenge of this topic is directed toward the synthesis of new insensitive energetic ingredients, it can only be achieved through a fundamental understanding of the underlying molecular and crystalline structural properties. The program will provide modeling of new ingredients with the appropriate structural criteria solving long standing issues of sensitivity and performance. This program addresses the fundamental chemistry and physics underpinning the energetic ingredient conflict: Significant enhancements in delivered energy in compact volumes while remaining resistant to catastrophic failure in extremely stressful environments. Solving these conflicting requirements will save lives making this initiative critical to Navy and Marine Corps operations.

PHASE I: Models will be developed based on the six (6) empirical observations below which will provide the foundation upon which proposed research efforts can be measured. Models developed provide theoretical results for materials which can then be synthesized in laboratories before being handed off to private industry for full scale development.
1. Increase Hydrogen Bonding; Impart high levels of hydrogen bonding to the molecules to increase the heat capacity of the compounds. This should allow the materials to dissipate the heat in a manner other than breaking bonds and consequently detonating.
2. Delocalize Electron Density in Nitro Groups; Design compounds in which the electron density is spread from the nitro groups to surrounding groups. This increases bond order between the nitro group and the atom to which it is bound; the resulting charge distribution should render the molecule more stable.
3. Utilize Coulombic Attractions to Stabilize the Ground-State Structure; Stabilize the ground-state geometry by designing structures whose sigma or pi framework have alternating positive and negative charges.
4. Reduce the Number of Nitro Groups; Impart stability to these molecules, by including energetic oxygen functionality in groups other than nitro groups, such as N-Oxides.
5. Avoid High Acidity; High acidity reduces the formulation compatibility of an explosive; measures to avoid high acidity such as using imidazole rings and aminating to block hydrogen should be explored.
6. Maximize Crystal Packing Planarity; Design compounds with linear planar two dimensional atomic arrangements to minimize slip plane resistance to shock and shear ignition mechanisms.

PHASE II: The energetic materials modeled and synthesized during phase one will be scale-up to the one-pound laboratory batch process. Process optimization and cost reduction steps will be sought and integrated into a final date package or Standard Operating Process (SOP) that can be provided to venders for large scale production. Testing will be conducted on the material to determine the energy content and evaluate the physical and mechanical properties.

PHASE III: A final down selection to the most optimum and IM compliant ingredient will be scaled to 5 – 10 pound batch or continuous process. The material will undergo initial formulation and processing in pint to 1 gallon mixes to determine IM and performance properties. Collaboration with a government lab is encouraged. The material will be tested for the following properties:
1. Down select to best material for 5-10 pound process validation.
2. Formulate pint to 1 gallon mixes of energetic material to determine compatibility and processing requirements.
3. Measure heat content via bomb calorimeter.

4. Determine the physical and mechanical properties.
5. Conduct preliminary IM testing on energetic material.
6. Conduct preliminary energetic qualification.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: N/A

REFERENCES:
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3. Philip E. Eaton 1 *, Mao-Xi Zhang 1, Richard Gilardi 2, Nat Gelber 3, Sury Iyer 3, Rao Surapaneni 3, Prop., Explos., Pyrotech, 27, 1, 2002.

4. A.T. Nielsen, S. Barbara, Caged Polynitramine Compound, U.S. Patent 5,693,794, 1997-12-02

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7. S.V. Zybin, W.A. Goddard III, P. Xu, A.C.T. van Duin, and A.P. Thompson, "Physical mechanism of anisotropic sensitivity in pentaerythritol tetranitrate from compressive-shear reaction dynamics simulations", Appl. Phys. Lett., 96, 081918, (2010).

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KEYWORDS: Insensitive Munitions;Hydrogen Bonding; Nitro Groups;Crystal Packing Planarity; Molecular Design Modeling; Ammonium Perchlorate

N12A-T024 TITLE: Chalcogenide Infrared Fiber Manufacturing Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify the major issues limiting the mechanical strength and power transmittance of the As2S3 chalcogenide infrared fiber and develop manufacturing technology for long length (> ten meters) applications and increased mechanical strength and optical transmission.

DESCRIPTION: The As2S3 fibers are critical to the implementation of a new design for a Directed InfraRed CounterMeasure system (DIRCM). DIRCM systems are essential to defeating the new generations of infrared guided missile threats to tactical aircraft. Utilizing these fibers allows a system design that can achieve the performance required of a DIRCM system, including the stringent weight limits, size and power levels acceptable for the H-1 series helicopters deployed by the Navy and Marine Corps. The fiber-based system design has also been demonstrated as effective for use on the larger H-60 series and V-22 aircraft operational in the Navy and Marine Corps. Alternative DIRCM system designs are considerably heavier, more expensive and do not allow for Open System Architecture, whereby the laser and pointer are separately replaceable units.

The major issue with fabrication of the As2S3 fiber-based system with long length fibers, lengths exceeding 10 meters, is loss of laser power during transmission. Losses are due to various impurities in the As2S3 materials, including absorbed contaminants in the fiber and imperfections introduced in the drawing process. The major impurities such as hydrogen sulfide (HS) are difficult to reduce to the extremely low levels (sub-ppm) required. The imperfections introduced during drawing can include but are not limited to, non-uniformity of the acrylate coating, off-center positioning of the core within the cladding, defects in the fiber [1], and induced loss due to environmental factors such as humidity and temperature.

A second issue is the mechanical strength of the fiber. Embedded particulates and imperfections are a known cause of fiber failures under stress. Measurements of the tensile strengths of chalcogenide, including As2S3, fibers show values considerably lower than the theoretical value [2]. The program objectives of this topic are for the fibers to be manufactured in lengths exceeding 10 meters and for them to pass a tensile proof test of at least 20kpsi and possess an optical loss of <0.15dB/m.

The Navy will only fund proposals that are innovative, address materials and manufacturing R&D and involve technical risk.

PHASE I: Identify the impurity levels needed for producing low-loss fibers and develop concepts for manufacturing processes to provide suitably pure materials. Define the bounds of the environmental conditions necessary for producing fibers of consistent quality as well as the methods for controlling the conditions. Identify the critical steps and components of the fiber drawing process and equipment and define a manufacturing process for drawing low-loss, high tensile strength fibers.

PHASE II: Build or assemble a prototype IR fiber drawing system capable of delivering high quality fiber with high yield. Demonstrate the operation of the system including measurements to verify the quality of the fiber produced.

PHASE III: Transition the process for creating a manufacturing capability for producing the IR fibers in quantity by providing a detailed description of how high quality fibers can be produced with high yield.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The IR fibers transmit in the infrared fingerprint region and so would be suitable for remote chemical sensing and other commercial applications.

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1. “Effect of scattering centers on the optical loss of As2S3 glass fibers in the infrared”, J. Appl. Phys. 75 (10) (1994) 4885-4891.

2. “Strength and fractographic analysis of chalcogenide As-S-Se and Ge-As-Se-Te glass fibers”, J. B. Quinn, V. Q. Nguyen, J. S. Sanghera, I. K. Lloyd, P. C. Pureza, R. Miklos and I. D. Aggarwal. J. Non-Crystalline Solids 325 [1-3] (2003) 150-157.

KEYWORDS: IR Fibers, Chalcolgenide, DIRCM, mechanical strength, optical transmission, fiber drawing

N12A-T025 TITLE: <u>Fortifying Data-at-Rest Encryption with a Credential/Functional-Based Encryption Layer</u>

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: Computer Network Defense - ACAT IV

OBJECTIVE: Investigate innovative and cost-effective techniques and algorithms to strengthen data-at-rest encryption by incorporating user's credentials (i.e. clearances) as part of the encryption scheme.

DESCRIPTION: Traditional public-key encryption involves a user encrypting data using the recipient's public key. The recipient is able to decrypt and access the encrypted data using his/her own private key. While this has been a standard philosophy for data confidentiality, it still does not address the case where a recipient has the authority to access the data. Consider the case where encrypted data must be decrypted only by users who possess Clearance A. Prior to encryption, the user that encrypts the data could consult a database or a trusted authority that can verify the recipient's credentials. However, if this is not feasible due the sensitivity of the clearance or the requested user's privileges, the encrypted data should not be transmitted as the recipient may not be authorized to access it with their current clearance level.

Functional encryption, a relatively new system to the cryptography community, uses the philosophy that data can be encrypted with an access policy. This eliminates the need to determine whether the intended recipient should access the decrypted data. If the intended recipient is part of the access policy, he/she is able to decrypt and access the encrypted information. Another application is the case where a user wishes to encrypt data whose intended recipient is specifically unknown but is part of a set of individuals with appropriate credentials. Functional encryption overcomes the unknown by simply encrypting the data with the access policy. Any one individual within the designated set would be able to decrypt and access the information.

Data-at-rest security is one of the key components of the Navy/Marine Corps Intranet (NMCI), providing full encryption of user data stored on secondary storage (i.e. hard drives) and protection against the disclosure of the stored user data if physically compromised. While the use of a PKI certificate and/or username/password combination have proven their strengths, adding an additional layer of encryption via functional encryption has the potential of providing greater assurance in the confidentiality of user data.

PHASE I: Research functional encryption techniques and algorithms and determine the best application of it towards currently utilized data-at-rest encryption systems. Research must include proof that the techniques and algorithms are feasible, secure, efficient, and interoperable with existing data-at-rest encryption systems.

PHASE II: Design a prototype/proof-of-concept that makes use of the functional encryption techniques and algorithms that current data-at-rest encryption systems can use. The prototype/proof-of-concept should illustrate efficiency and the feasibility of the research developed in Phase I.

PHASE III: Transition the technology into current data-at-rest encryption systems.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Functional encryption can also be utilized by the private sector to provide an additional layer of security and assured resistance to information leakage.

REFERENCES:
1. Amit Sahai and Hakan Seyalioglu. 2010. Worry-free encryption: functional encryption with public keys. In Proceedings of the 17th ACM conference on Computer and communications security (CCS '10). ACM, New York, NY, USA, 463-472. DOI=10.1145/1866307.1866359 http://doi.acm.org/10.1145/1866307.1866359

2. Dan Boneh, Amit Sahai, and Brent Waters. 2011. Functional encryption: definitions and challenges. In Proceedings of the 8th conference on Theory of cryptography (TCC'11), Yuval Ishai (Ed.). Springer-Verlag, Berlin, Heidelberg, 253-273.

KEYWORDS: cryptography; data-at-rest; functional encryption; public key cryptography; attribute-based-encryption; predicate encryption

N12A-T026 TITLE: <u>Wide-area Motion Imagery and Radio Frequency Compressive Sensing Applications</u>

TECHNOLOGY AREAS: Information Systems, Sensors, Battlespace

ACQUISITION PROGRAM: Distributed Common Ground Station - Navy (DCGS-N) ACAT I

OBJECTIVE: Investigate algorithms that use compressive sensing to improve processing, delivery, and storage of wide-area surveillance products such as radio frequency and wide-area motion imagery to save critical bandwidth and accelerate detection, recognition and tracking for tactical users.

DESCRIPTION: Compressive sensing is a relatively new form of data sampling that shows promise to greatly reduce the amount of information that is required to acquire and reconstruct information from sources such as radio frequency, synthetic aperture radar, and electro-optical sensors. The theory of compressive sensing has some interesting practical applications in the processing and exploitation of images, signals and other structured data. In some cases it can be used as an improved form of compression and reconstruction of sensor data. In other cases it can be used to detect, classify and estimate with reduced dimensionality and thereby provide increased operational rates over the original sources. These particular applications of compressive sensing lend themselves well to address the various applications of wide-area persistent surveillance.

Intelligence, Surveillance, and Reconnaissance sensors are now producing data that has greater density and wider field of regard. These sensors are being integrated into a mix of manned and unmanned platforms which will provide an increasing persistent stare over large areas. The volume and amount of dense media being produced is already beyond the capacity of analysts to review. As a result, automated exploitation is more important than ever. The dense sensor media sometimes cannot be reasonably distributed in raw form across the Global Information Grid (GIG). Innovative techniques are needed to accomplish this on the sensor and on the server which receives and distributes the exploitated data product.

In order to address wide-area persistent surveillance in its operational form, the algorithms should be applied to some degree on the sensor platforms as well as the sensor server platforms across the GIG, and for automated exploitation in server farm concentrator points. For instance, in wide-area video, compressive sensing could speed up regional detections and stream high resolution areas of interest and lower resolution backgrounds for reference. Such applications can be applied to maritime operations where vessel detection could occur on shipboard sensors and for higher order ship classification at a ground station server.

PHASE I: Research uses of compressive sensing algorithms to find the best application areas to speed up exploitation and distribution of media produced by wide-area persistent surveillance sensors. Develop small illustrative prototype implementations and experiments that prove the feasibility for improvements and the qualitative aspects of the proposed implementations.

PHASE II: Design a prototype compressive sensing software application suite that can address processing on the sensor platform as well as on a DCGS-N server. The prototype should illustrate techniques that automatically detect areas of concern and reduce the need to send wide-area surveillance data across the GIG. The system should focus on compression, reconstruction, and detection and also assist higher level functions such as identification, tracking and behavioral clues. Prototype demonstration could be at the SECRET classification level.

PHASE III: Transition the technology into the Distributed Common Ground Station - Navy system to allow it to handle wide-area surveillance products from unmanned aircraft systems and shipboard surveillance systems.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Homeland security and port security can all use wide-area surveillance applications.

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1. Zhi Tian and Georgios B. Giannakis, Compressed Sensing For Wideband Cognitive Radios, ICASSP, IEEE, 2007

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3. Kalyani Krishnamurthy, Maxim Raginsky and Rebecca Willett, Hyperspectral Target Detection From Incoherent Projections, Department of Electrical and Computer Engineering, Duke University, Durham, NC 27708

KEYWORDS: compressive sensing; wide-area motion imagery (WAMI); persistent surveillance; video classification; imagery; sensors