DEPARTMENT OF THE NAVY (DoN)
15.A Small Business Technology Transfer (STTR)
Proposal Submission Instructions

Revised Closing Date: February 25, 2015, at 6:00 a.m. ET

INTRODUCTION

Responsibility for the implementation, administration, and management of the Department of the Navy (DoN) STTR Program is with the Office of Naval Research (ONR). If you have questions of a general nature regarding the Navy's STTR Program, contact Ms. Lore-Anne Ponirakis (loreanne.ponirakis@navy.mil). For program and administrative questions, please contact the Program Managers listed in Table 1; **do not** contact them for technical questions. For technical questions about a topic, you may contact the Topic Authors listed for each topic during the period **12 December 2014 through 14 January 2015**. Beginning **15 January 2015**, the SBIR/STTR Interactive Technical Information System (SITIS) (www.dodsbir.net/sitis) listed in Section 4.15.c of the DoD STTR Program Solicitation must be used for any technical inquiry. For inquiries or problems with electronic submission, contact the DoD SBIR/STTR Help Desk at [1-800-348-0787] or Help Desk email at [sbirhelp@bytecubed.com] (8:00 a.m. to 5:00 p.m. ET).

TABLE 1: NAVY SYSTEMS COMMANDS (SYSCOM) STTR PROGRAM MANAGERS

Topic Numbers	Point of Contact	Activity	Email
N15A-T001 thru N15A-T009	Ms. Dusty Lang	NAVAIR	navair.sbir@navy.mil
N15A-T010 thru N15A-T012	Mr. Dean Putnam	NAVSEA	dean.r.putnam@navy.mil
N15A-T013 thru N15A-T023	Ms. Lore-Anne Ponirakis	ONR	loreanne.ponirakis@navy.mil

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 SBIR/STTR Web site at www.navysbir.com**.** Additional information pertaining to the DoN's mission can be obtained from the DoN website at www.navy.mil**.**

PHASE I GUIDELINES

Follow the instructions in the DoD STTR Program Solicitation at www.dodsbir.net/solicitation for program requirements and proposal submission guidelines. Please keep in mind that Phase I should address the feasibility of a solution to the topic. It is highly recommended that proposers follow the Navy proposal template located at www.navysbir.com/submission.htm as a guide for structuring proposals. Inclusion of cost estimates for travel to the sponsoring SYSCOM's facility for one day of meetings is recommended for all proposals.

Technical Volumes that exceed the **20** page limit will be reviewed only to the last word on the **20th** page. Information beyond the **20th** page will not be reviewed or considered in evaluating the proposal. To the extent that mandatory technical content is not contained in the first 20 pages of the proposal, the evaluators may deem the proposal as non-responsive and score it accordingly.

The Navy requires proposers to include, within the **20-page limit**, an option that furthers the effort and will bridge the funding gap between Phase I and the Phase II start. Phase I options are typically exercised upon the decision to fund the Phase II. **The Phase I base amount and Period of Performance shall not exceed $80,000 and seven months**; **the Phase I option amount and Period of Performance shall not exceed $70,000 and six months.**

PHASE I PROPOSAL SUBMISSION CHECKLIST:

The following criteria must be met or the proposal will be REJECTED.

1. **Include a header with company name, DoD proposal number, and DoD topic number on each page of your Technical Volume.**

2. **Include tasks (separately) to be completed during the option period in the 20 page Technical Volume and include the costs as a separate section in the Cost Volume. Costs for the base and option should be clearly separate, and identified on the Proposal Cover Sheet, in the Cost Volume, and in the work plan section of the proposal.**

3. **BREAK OUT SUBCONTRACTOR, MATERIAL AND TRAVEL COSTS IN DETAIL. In the cost volume, it is important to provide sufficient detail for the subcontract, material and travel costs. Subcontractor costs should be detailed at the same level as the prime to include at a minimum personnel names, rate per hour, number of hours, material costs (if any), and travel costs (if any). Material costs should include at a minimum listing of items and cost per item. Travel costs should include at a minimum the purpose of the trip, number of trips, location, length of trip, and number of personnel. Use the "Explanatory Material Field" in the DoD Cost Volume worksheet for this information.**

4. **If Discretionary Technical Assistance (DTA) is proposed, add information required to support DTA in the "Explanatory Material Field" in the DoD Cost Volume worksheet.**

5. **The Phase I base effort and Period of Performance shall not exceed $80,000 and seven months. The Phase I Option amount and Period of Performance shall not exceed $70,000 and six months. The costs for the base and option are clearly separate, and identified on the Proposal Cover Sheet, in the Cost Volume, and in the Technical Volume. If proposing direct DTA, a total of up to $5,000 combined may be added to the Base and Option periods.**

6. **Upload the Technical Volume and the DoD Proposal Cover Sheet, the DoD Company Commercialization Report, and Cost Volume electronically through the DoD submission site (https://www.dodsbir.net/submission/SignIn.asp) by 6:00 a.m. ET, 25 February 2015.**

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

PHASE II GUIDELINES

All Phase I awardees will be allowed to submit an **Initial** Phase II proposal for evaluation and selection. The Phase I Final Report, Initial Phase II Proposal, and Transition Outbrief (as applicable), will be used to evaluate the offeror's potential to progress to a workable prototype in Phase II and transition technology in Phase III. Details on the due date, content, and submission requirements of the Initial Phase II proposal will be provided by the awarding SYSCOM either in the Phase I award or by subsequent notification.

NOTE: All SBIR/STTR Phase II awards made on topics from solicitations prior to FY13 will be conducted in accordance with the procedures specified in those solicitations (for all DoN topics, this means by invitation only).

Section 4(b)(1)(ii) of the SBIR Policy Directive permits the Department of Defense and by extension the DoN, during fiscal years 2012 through 2017, to issue a Phase II award to a small business concern that did not receive a Phase I award for that R/R&D. **NOTE:** The DoN will NOT be exercising this authority for STTR Phase II awards. **Therefore, in order for any small business firm to receive a Phase II award, the firm must be a recipient of a Phase I award under that topic and submit an Initial Phase II proposal.**

The Navy typically awards a cost plus fixed fee contract for Phase II. The Phase II contracts can be structured in a way that allows for increased funding levels based on the project's transition potential. This 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 subsequent Phase II award. For existing Phase II contracts, increased funding levels can be attained through contract expansions, some of which may exceed the $1,000,000 recommended limits for Phase II awards.

DISCRETIONARY TECHNICAL ASSISTANCE

The STTR Policy Directive section 9(c), allows the DoN to provide discretionary technical assistance (DTA) to its awardees to assist in minimizing the technical risks associated with STTR projects and commercializing into products and processes. Firms may request, in their Phase I and Phase II proposals, to contract these services themselves in an amount not to exceed $5,000 per year. This amount is in addition to the award amount for the Phase I or Phase II project.

Approval of direct funding for DTA will be evaluated for approval by the DoN STTR office if the firm's proposal (1) clearly identifies the need for assistance, (2) provides details on the provider of the assistance (name and point of contact for performer); and unique skills/specific experience to carry out the assistance proposed, and (3) the cost of the required assistance (costs and hours proposed or other details on arrangement). This information must be included in the firm's cost proposal specifically identified as "Discretionary Technical Assistance" and cannot be subject to any profit or fee by the requesting SBIR firm. In addition, the provider of the DTA may not be the requesting firm, an affiliate of the requesting firm, an investor of the requesting firm, or a subcontractor or consultant of the requesting firm otherwise required as part of the paid portion of the research effort (e.g. research partner). Failure to include the required information in the proposal will result in the request for DTA being disapproved. Exceeding proposal limits identified for Phase I ($150,000 for Base, Option, and DTA) without including the required identification of DTA will result in the proposal's REJECTION without evaluation.

Phase I awardees that propose more than $150,000 in total funding (Base, Option and DTA) cannot receive a purchase order. Purchase orders are a type of Simplified Acquisition Procedure (SAP) intended to reduce administrative costs, promote efficiency and economy in contracting, and avoid unnecessary burdens for agencies and contractors. The need to issue a Firm Fixed Price (FFP) contract may result in contract delays if the SYSCOM normally issues purchase orders for Phase I awards.

If a firm requests and is awarded DTA in a Phase II proposal, it will be eliminated from participating in Navy Transition Assistance Program (TAP), the Navy Opportunity Forum, and any other assistance the Navy provides directly to awardees.

All Phase II awardees not receiving funds for DTA in their award must attend a one-day Navy TAP meeting during the second year of the Phase II. This meeting is typically held in the summer in the

Washington, D.C. area. Information can be obtained at: 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.

PHASE III GUIDELINES

A Phase III STTR award is any work that derives from, extends, or completes effort(s) performed under prior STTR funding agreements, but is funded by sources other than the STTR Program. Thus, any contract or grant where the technology is the same as, derived from, or evolved from a Phase I or a Phase II SBIR/STTR contract and awarded to the company that was awarded the Phase I/II STTR is a Phase III STTR contract. This covers any contract/grant issued as a follow-on Phase III STTR award or any contract/grant award issued as a result of a competitive process where the awardee was an STTR firm that developed the technology as a result of a Phase I or Phase II STTR. The Navy **will** give STTR Phase III status to any award that falls within the above-mentioned description, which includes assigning STTR Data Rights to any noncommercial technical data and/or noncommercial computer software delivered in Phase III that was developed under STTR Phase I/II effort(s). Government's prime contractors and/or their subcontractors follow the same guidelines as above and ensure that companies operating on behalf of the Navy protect the rights of the STTR company.

EVALUATION AND SELECTION

The Navy will evaluate and select Phase I and Phase II proposals using the evaluation criteria in Sections 6.0 and 8.0 of the DoD STTR Program Solicitation respectively, with technical merit being most important, followed by qualifications of key personnel and commercialization potential of equal importance. 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. **NOTE: The Navy does NOT participate in the FAST Track program.**

Protests of Phase I and II selections and awards shall be directed to the cognizant Contracting Officer for the Navy Topic Number. Contact information for Contracting Officers may be obtained from the Navy SYSCOM SBIR Program Managers listed in Table 1.

One week after Phase I solicitation closing, e-mail notifications that proposals have been received and processed for evaluation will be sent. Consequently, e-mail addresses on the proposal coversheets must be correct.

The Navy typically awards a Firm Fixed Price (FFP) contract or a small purchase agreement for Phase I.

In accordance with section 4.10 of the DoD SBIR Instructions, requests for a debrief must be made within 30 days of non-award notification.

CONTRACT DELIVERABLES

Contract deliverables are typically progress reports and final reports. Deliverables required by the contract, shall be uploaded to https://www.navysbirprogram.com/navydeliverables/.

AWARD AND FUNDING LIMITATIONS

In accordance with STTR Policy Directive section 4(b)(5), there is a limit of one sequential Phase II award per firm per topic. Additionally in accordance with STTR Policy Directive section 7(i)(1), each award may not exceed the award guidelines (currently $150,000 for Phase I and $1 million for Phase II, excluding DTA) by more than 50% (SBIR/STTR program funds only) without a specific waiver granted by the SBA.

TOPIC AWARD BY OTHER THAN THE SPONSORING AGENCY

Due to specific limitations on the amount of funding and number of awards that may be awarded to a particular firm per topic using SBIR/STTR program funds (see above), Head of Agency Determinations are now required (for all awards related to topics issued in or after the SBIR 13.1/STTR 13A solicitation) before a different agency may make an award using another agency's topic. This limitation does not apply to Phase III funding. Please contact the original sponsoring agency before submitting a Phase II proposal to an agency other than the one that sponsored the original topic. (For DoN awardees, this includes other Navy SYSCOMs.)

TRANSFER BETWEEN SBIR AND STTR PROGRAMS

Section 4(b)(1)(i) of the STTR Policy Directive provides that, at the agency's discretion, projects awarded a Phase I under a solicitation for STTR may transition in Phase II to SBIR and vice versa. A firm wishing to transfer from one program to another must contact its designated technical monitor to discuss the reasons for the request and the agency's ability to support the request. The transition may be proposed prior to award or during the performance of the Phase II effort. Agency disapproval of a request to change programs will not be grounds for granting relief from any contractual requirements. All approved transitions between programs must be noted in the Phase II award or an award modification signed by the contracting officer that indicates the removal or addition of the research institution and the revised percentage of work requirements.

ADDITIONAL NOTES

1. The Naval Academy, the Naval Postgraduate School and other military academies are government organizations but now qualify as partnering research institutions. However, Navy laboratories DO NOT qualify as a research partner. Navy laboratories may be proposed only IN ADDITION TO the partnering research institution.

2. Due to the short time frame associated with Phase I of the STTR process, the Navy does not recommend the submission of Phase I 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 goal for time to award. 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 the Navy's evaluation, but requiring IRB approval may delay the start time of the Phase I award and if approvals are not obtained within two months of notification of selection, the decision to award may be terminated. If the use of human, animal, and recombinant DNA use is included under a Phase I or Phase II proposal, please carefully review the requirements at http://www.onr.navy.mil/About-ONR/compliance-protections/Research-Protections/Human-Subject-Research.aspx**.** This webpage provides guidance and lists approvals that may be required before contract/work can begin.

3. Due to the typical length of time for approval to obtain Government Furnished Equipment (GFE), it is recommended that GFE is not proposed as part of the Phase I proposal. If GFE is proposed and is determined during the proposal evaluation process to be unavailable, proposed use of GFE may be considered a weakness in the proposal

NAVY STTR 15.A Topic Index

NAVY STTR 15.A Topic Descriptions

N15A-T001 TITLE: Reliable, Safe, Lithium-ion Battery Enabled by a Robust Battery Management System

TECHNOLOGY AREAS: Air Platform, Sensors, Electronics

OBJECTIVE: Develop a Battery Management System (BMS) that is autonomously capable of controlling performance and monitoring battery health. Integrate the BMS to develop a functioning, comprehensive Lithium-ion (Li-ion) battery product.

DESCRIPTION: The Li-ion battery has emerged as the power source of choice in many applications due to its high energy density, long life, low self-discharge and lightweight features. A collection of individual Li-ion cells forms a "module" and a collection of modules forms a "pack". A Li-ion battery product is formed by a collection of modules and packs, which are designed to produce the required electrical power system parameters such as current, voltage, power, capacity and energy. In addition to the cells, the battery consists of wires, connectors, and electronic circuitry which make up the battery management system. The BMS monitors the cell/module/pack performance parameters mentioned above. It is an important component in the overall product; it is the "brains" of the Li-ion battery that monitor and control the operation of the battery under use/abuse conditions to deliver the power output in a safe and reliable manner during the life cycle.

The introduction of Li-ion batteries in the aviation industry has led to roadblocks, such as the fire damage of a Boeing Dreamliner caused by a Li-ion battery, forcing grounding of the fleet. Compared to the other battery chemistries, Li-ion chemistries are much less tolerant of abusive conditions such as over-charge/discharge, high-temperature, or electric shock. The BMS is the key component of the battery that continuously monitors, assesses, and controls the cells, modules, and pack under the following operating conditions: temperature, altitude, humidity, and salt-fog. Lack of maturation of BMS technology is the current roadblock preventing the development of a comprehensive battery product and realizing the full potential of the Li-ion chemistry [1, 5-7].

The features of a robust BMS to be developed should include: advanced/novel sensing techniques, modeling, control and diagnostics and advanced diagnostic systems. The key attributes of a high fidelity system architecture should consist of (i) monitoring (voltage [individual, pack, module, system], current, temperature, exposure to environments [moisture, pressure, salt-fog], cell balancing), (ii) state (charge, health, number of charge/discharge cycles/processes, remaining capacity), (iii) management (data acquisition, standard communication protocol, thermal design, charge control) and (iv) system integration (over-charge/discharge, abnormal conditions, safety and protection, fault detection and alarm, built-in-tests (BITs) for safety compromise alert, diagnostic tests to detect battery nominal and degraded states). The BMS must be a scalable system ranging from around 1 Kilowatt hour (kWh) up to 1 Megawatt hour (MWh) with operational ranges from nominal 28 Volts Direct Current (VDC) up to 400 VDC. Firmware components must comply with MIL-STD-704F [3] and industrial standards. An option for the BMS is to have telemetry that allows real-time wireless monitoring of all battery parameters.

This effort is looking to develop a fully functional Li-ion battery product with a robust BMS that can autonomously and accurately display battery system performance metrics in real time. The fully functional battery must meet the requirements called out in MIL-PRF-29595A [2] and NAVSEA S9310-AQ-SAF-010 [4], which are performance and safety specifications, respectively.

PHASE I: Develop proof of concept for the functionality of a robust, high fidelity battery management system. Determine feasibility for integration into a Li-ion battery product.

PHASE II: Develop a Li-ion battery prototype by integrating robust BMS architectures to demonstrate the functionality in a lab environment.

PHASE III: Finalize BMS for production, to include: hardware (communication ports, charge control, data acquisition, thermal management, sensor monitors, and safety circuits), software (state of health (SOH), state of charge (SOC), and fault detection), and firmware elements (functional status algorithms and built-in-test (BIT) mechanisms to protect the battery). Demonstrate the BMS integrated Li-ion battery product that meets the electrical needs of aircraft in a safe and effective manner in an operational environment, obtain flight certification and transition the technology to appropriate Navy platforms (Ex. F/A-18E/F, H-60, and F-35).

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Li-ion batteries are gaining popularity in commercial aircraft applications. Improvements made under this topic would be directly applicable to the commercial aviation fleet.

REFERENCES:
1. Lu, L., Han, X., Li, J., Hua, J., & Ouyang, M. (2013). A review on the key issues for lithium-ion battery management in electric vehicles. Journal of Power Sources, 226, 272 – 288. doi:10.1016/j.jpowsour.2012.10.060

2. MIL-PRF-29595A - Performance Specification: Batteries and Cells, Lithium, Aircraft, General Specifications for (26 April 2011) http://www.everyspec.com/MIL-PRF/MIL-PRF-010000-29999/MIL-PRF-29595A_32803/

3. MIL-STD-704F, Military Standard: Aircraft Electric Power Characteristics (12 MARCH 2004) http://www.everyspec.com/MIL-STD/MIL-STD-0700-0799/MIL-STD-704F_1083/

4. NAVSEA S9310-AQ-SAF-010 (Second Revision) Technical Manual for Navy Lithium Battery Safety Program Responsibilities and Procedures, 15 July 2010. Retrieved from http://www.public.navy.mil/comnavsafecen/Documents/afloat/Surface/CS/Lithium%20Batteries%20Info/LithBatt_NAVSEA_TMS9310.pdf

5. Spotnitz, R., & Franklin, J. (2003) Abuse behavior of high-power, lithium-ion cells. Journal of Power Sources, 113(1), 81 -100. doi:10.1016/S0378-7753(02)00488-3

6. Stuart, T. A., & Zhu, W. (2011). Modularized battery management for large lithium ion cells. Journal of Power Sources, 196(1), 458 – 464. doi:10.1016/j.jpowsour.2010.04.055

7. Vetter, J., Novák,P., Wagner, M.R., Veit, C., Möller, K.C., Besenhard, J.O.,Winter, M., Wohlfahrt-Mehrens, M., Vogler, C., & Hammouche, A. (2005) Ageing mechanisms in lithium-ion batteries. Journal of Power Sources, 147(1-2), 269 – 281. doi:10.1016/j.jpowsour.2005.01.006

KEYWORDS: Battery Management System; Li-ion battery; Safety System; Battery fault diagnosis; Battery states estimation; Cell performance metrics

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T002 TITLE: <u>Improved Turbulence Modelling Across Disparate Length Scales for Naval Computational Fluid Dynamics Applications</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop improved numerical methods for predicting the unsteady turbulent flows that dominate naval aviation.

DESCRIPTION: Highly unsteady vorticity-dominated turbulent flows are significant drivers of aircraft performance; moreover, operating in the naval environment adds additional complexities that are truly unique and directly impact safety and mission success. For example, approaching and landing on the back of a pitching and heaving small-deck ship is one the most challenging tasks faced by rotary-wing naval aviators. In addition to the difficulties related to ship motion and weather, the airwake associated with the ship, which contains a complicated set of turbulent vortical structures of varying length scales, can persist for many ship lengths downwind. The interaction of this ship airwake with the approaching aircraft directly impacts aircraft aeromechanics through complicated fluid dynamics and fluid-structural dynamics interactions.

In recent years, advancements in computational fluid dynamics (CFD) methods (large eddy simulation [LES], detached eddy simulation [DES], unsteady Reynolds-averaged Navier-Stokes [URANS] and their variation) have demonstrated their ability to predict rotorcraft aeromechanics (Ref 1 and 2) and ship airwakes near to the deck (Ref 3 and 4). However, there are vastly different lengths and time scales associated with rotor tip vortices (measured in inches) and the vortical structures shed from the ship (measured in multiple feet). Predicting fully-resolved (spatially and temporally) rotorcraft-ship airwake interactions in the far wake using these CFD methods will be unlikely for many years to come without major simplifications of the physics. It is exactly this issue that the proposed effort seeks to address. The Navy solicits innovative methods for addressing these disparate length scales and maintaining the necessary accuracy at minimal computational effort.

For example, it has been shown that vorticity-velocity formulations of the Navier-Stokes equations can maintain vorticity on coarser grids than conventional pressure, velocity, and density CFD formulations (Ref 5 and 6). Furthermore, the addition of numerical viscosity to stabilize traditional numerical methods not only diffuses the types of vortical structures prevalent in the wakes of ships and rotorcraft over time, but may also temporally smooth out the inherent instabilities in the underlying physics associated with the cascade of energy from large- to small-scale turbulent structures. The objective of this effort is to develop efficient turbulence modeling by understanding some of the assumptions that have been made in the development of contemporary CFD solvers. The following questions should be addressed in this effort: the role of symmetric vs. non-symmetric assumptions in the viscous stress tensor represented on a finite size mesh, how to efficiently model the growth of small-scale turbulent structures without refining down to Kolmogorov's scale, and understanding the tradeoffs associated with vorticity-velocity versus traditional CFD formulations. It should be noted that the aforementioned observations on the vorticity-velocity formulation are used for illustrative purposes and are not meant to imply an approach to this topic.

PHASE I: Formulate and define a theoretical basis for turbulence modeling. Demonstrate feasibility through the prediction of unsteady vorticity-dominated flows through comparison of the new approach to existing turbulence models. Key metrics include changes in length scales that can now be resolved (versus being modeled) and computational complexity of the algorithm, including changes in floating point operations.

PHASE II: Develop new CFD analysis on classical turbulence problems and problems of interest to the Navy. Demonstrate prototype turbulence modeling software capable of predicting: ship airwake turbulence during aircraft launch and recovery; wing low speed, high lift flows with extended flap systems; aircraft-to-aircraft formation flight interactional aerodynamics; rotorcraft downwash/wake ground interference; and transonic shock / boundary layer interactions.

PHASE III: Commercialize and transition the technology for improved predictions of ship airwake, dynamic interface, rotorwash, formation flight and rotorcraft performance. This will involve a detailed verification and validation effort along with a demonstration of application capability in a production-type and widely used tool. This phase would likely include integration within the US Department of Defense (DoD) primary tools being developed within the Computational Research and Engineering Acquisition Tools and Environments (CREATE-AV) program. The details of working with the CREATE-AV team will be developed through close coordination with the NAVAIR engineers who are assigned to the CREATE-AV quality assurance team.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: While the Navy has a very unique environment with regards to shipboard launch and recovery, this technology would also be useful for other complex wake interactions. Improvement to CFD codes resulting from the work would be applicable to interactions ranging from wind gust interactions between city buildings to the complex flow field emanating from the nose of a race car and interacting with the rear wing. Anything that CFD is used on in the commercial world could benefit from this work.

REFERENCES:
1. Lim, J.W., Wissink, A., Jayaraman, B., & Dimanlig, A. (2012). Helios adaptive mesh refinement for HART II rotor wake simulations. Paper presented at the 68th Annual Forum of the American Helicopter Society, Fort Worth, TX. Retrieved from: http://arc.aiaa.org/doi/abs/10.2514/6.2012-713

2. Biedron, R.T. & Lee-Rausch, E.M. (2011). Computation of UH-60A airloads using CFD/CSD coupling on unstructured meshes. Paper presented at the 67th Annual Forum of the American Helicopter Society, Virginia Beach, VA. Retrieved from: http://ntrs.nasa.gov/search.jsp?R=20110011257

3. Quon, E.W., Cross, P.A., Smith, M.J., Rosenfeld, N.C., & Whitehouse, G.R. (2014). Investigation of ship airwakes using a hybrid computational methodology. Paper presented at the 70th Annual Forum of the American Helicopter Society, Montreal, Canada.

4. Polsky, S.A. and Miklosovic, D.S. (2011). CFD study of bluff body wake from a hangar with comparison to experimental data. Paper presented at the 29th AIAA Applied Aerodynamics Conference, Honolulu, HI, AIAA-2011-3351. Retrieved from: http://arc.aiaa.org/doi/abs/10.2514/6.2011-3351

5. Whitehouse, G.R. & Boschitsch, A.H. (2013). Towards the next generation of grid-based vorticity-velocity solvers for general rotorcraft flow analysis. Paper presented at the 69th Annual Forum of the American Helicopter Society, Phoenix, AZ.

6. Harris, R.E., Sheta, E.S., Noack, R.W., & Sankaran, V. (2012). Rotorcraft flow modeling using hybrid vorticity transport and Navier-Stokes method. Paper presented at the 50th AIAA Aerospace Sciences Meeting, Nashville, TN, AIAA-2012-1102.

KEYWORDS: computational fluid dynamics; Turbulence models; vorticity-velocity formulation; helicopter/ship airwake interaction; Large Eddy Simulation; unsteady Reynolds-Averaged Navier-Stokes

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T003 TITLE: Novel Multi-scale/Multi-physics Integrated Tool for the Prediction of Manufacturing-Induced Defects in Autoclave Composite Airframe Parts

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop a multi-scale/multi-physics integrated analytical tool, which predicts manufacturing-induced defects due to material, part, tools and processes, which could be utilized directly in the design, analysis, and fabrication optimization of structural composite components.

DESCRIPTION: The use of advanced composites is common in modern aircraft structural components. Benefits of composite structures include reducing the overall weight and life cycle cost of the aircraft. The use of advanced polymer composite materials allows for the possibility of significant reductions in maintenance and fuel expenditures while increasing service life, leading to an overall cost benefit.

Defects are inevitable in any manufacturing process for composite structures. Reduction in the safe operating lifetime of composite structures with defects, compared to pristine structures, has shown that the presence of manufacturing defects is critical for determining component reliability. Even though damage mechanics is a well-established field with pre-existing analysis and methodologies to provide a basis for evaluation of composite response with induced defects, current approaches do not include the influence of manufacturing induced defects at the design stage. The current practice in most industry is to set thresholds for defects as accept/reject criteria. For instance, the aerospace industry rejects parts found to have more than 2% void volume fraction. In some cases, knockdown factors are applied based on empirical data relating defect densities to performance parameters such as stiffness and strength. This situation needs improvement by using modeling and simulation of the manufacturing process, accounting for tooling, machining and assembly in order to quantify the resulting “material state” of the manufactured part.

An innovative way to improve aircraft composite parts reliability is to perform research to identify methods of predicting and characterizing manufacturing defects. In order to achieve a proper cost/performance trade-off, it is imperative that a quantitative assessment on manufacturing defects is made with respect to their impact on the desired structural performance.

Currently a number of existing processing models can be used to generate useful composite defect predictions for very simple structures. However, few models can analyze all the major processing phenomena in complex composite components. Another drawback of available models is their use of simplified boundary conditions and/or processing cycles. Regardless of the level of sophistication with which material behavior and processing phenomena are modeled, useful manufacturing defect prediction cannot be obtained without an accurate description of the boundary conditions actually seen by the modelled components.

An analytical tool which identifies important processing parameters in an autoclave process, such as component internal temperature, resin kinetics, and resin rheology, autoclave pressure and vacuum pressure, and takes these effects into account explicitly would need to be based on stochastic simulations of composite manufacturing. This would allow quantification of process variability as a function of material selection and processing parameters. Optimization decisions could then be made at an early stage. An integrated model would be able to completely characterize system boundary conditions for different setups, including component design details with specific ply drop-offs, small radii curvatures, tool-part interaction, part geometry molding, and bagging conditions. This model would have a multi-scale approach in which manufacturing defect predictions of local models could be used in “global discretization” level models to predict the processing behavior of the largest components. Finally, the analytical tool should be multi-physics so that the chemical, thermal, and mechanical program modules can interact with a central database that will contain a complete description of the system.

The aim of this program is to develop an analytical tool that predicts manufacturing defects, including voids, ply waviness, delaminations, fiber wrinkling, resin starvation/rich areas, and warpage caused from tool-part interaction. The tool will identify the interdependency between processing parameters and part geometries in an autoclave. This tool should include the effects of process tooling, which affects component stiffness, thermal expansion, and friction/contact resistance characteristics. Component defect prediction results will be utilized directly in subsequent structural analysis of airframe components.

PHASE I: Develop an innovative approach for predicting manufacturing defects in thermoset composite airframe structure. Demonstrate the feasibility of the approach by performing initial predictions.

PHASE II: Develop and demonstrate the new analytical tool's capabilities through analysis of an airframe component. Verify and validate the results with publically available test data and a selective coupon test program.

PHASE III: Demonstrate full operational functionality in Navy-supported test scenarios. Transition the multi-scale/multi-physics tool for use with commercially available computational tools to predict process-induced manufacturing defects on Navy aircraft platforms and provide a detailed supportability plan.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The presence of defects on manufactured composite parts is a concern that the aerospace, boat building and automotive industries face. The developed technology could be integrated with commercial software to address improvements on structural design and performance, and will benefit in-service maintenance issues faced by these industries.

REFERENCES:
1. Mesogitis, T. S., Skordos, A. A., & Long, A. C. (2014). Uncertainty in the manufacturing of fibrous thermosetting composites: A review. Composites Part A: Applied Science and Manufacturing, 57, 67-75. doi:10.1016/j.compositesa.2013.11.004

2. Wang, J., Potter, K. D., & Etches, J. (2013) Experimental investigation and characterization techniques of compressive fatigue failure of composites with fibre waviness at ply drops. Composite Structures, 100, 398 – 403. doi:10.1016/j.compstruct.2013.01.010

3. Zeng, X., & Raghavan, J. (2010). Role of tool-part interaction in process-induced warpage of autoclave-manufactured composite structures. Composites Part A: Applied Science and Manufacturing, 41(9), 1174 – 1183. doi:10.1016/j.compositesa.2010.04.017

4. Kaushik, V., & Raghavan, J. (2010). Experimental study of tool-part interaction during autoclave processing of thermoset polymer composite structures. Composites Part A: Applied Science and Manufacturing, 41(9), 1210 – 1218. doi:10.1016/j.compositesa.2010.05.003

5. Johnston, A., Hubert, P., Fernlund, G., Vaziri, R., & Poursartip, A. (1996). Process Modeling of Composite Structures Employing a Virtual Autoclave Concept. Science and Engineering of Composite Materials, 5(3-4), 235-252. doi:10.1515/SECM.1996.5.3-4.235

6. Riddle, T. W., Cairns, D. S., & Nelson, J. W. (2013). Effects of Defects Part A: Stochastic Finite Element Modeling of Wind Turbine Blades with Manufacturing Defects for Reliability Estimation. 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference. doi:10.2514/6.2013-1627

KEYWORDS: Manufacturing; Composite; composite manufacturing process; composite manufacturing defects; composite manufacturing predictions; composite process induced warpage

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T004 TITLE: In-Air E-field Sensor for Airborne Applications

TECHNOLOGY AREAS: Air Platform, Sensors

OBJECTIVE: Develop an in-air, rotationally invariant Electric-field (E-field) sensor which can be used aboard a fixed wing aircraft or in a Tier 1 Unmanned Autonomous Vehicle (UAV).

DESCRIPTION: The Navy uses magnetometers for airborne submarine localization. One of the significant sources of noise for the magnetometers is geomagnetic noise (currents in the ionosphere). A second magnetometer/UAV can act as a reference sensor for the first system. The two systems must be separated sufficiently that only one would sense a target. The geomagnetic noise is coherent over tens of miles so that if the measured signals in the two systems are subtracted, the geomagnetic noise would be significantly reduced, but the target signature would remain. Since an electric field originating below the surface of the water will not significantly propagate into the atmosphere, an E-field sensor on the same platform could, if successful, provide a reference sensor for reduction of the geomagnetic noise without loss of target signal. This method requires less equipment and manpower, and could reduce the cost of the detection operation.

The first challenge to using an E-field sensor is that there are two possible ways to determine the sensitivity needed and they do not agree. A straightforward determination of the required E-field from the desired Magnetic field (B-field) obtained by multiplying by c (speed of light) indicates that the geomagnetic E-fields should be on the order of millivolts per meter (milliV/m). Yet ground based measurements of geomagnetic noise shows E-field values in the range of microvolts per meter (microV/m). The second challenge is designing a sensor with the required microvolt to millivolt sensitivity that is rotationally invariant and can be flown on an aircraft or Tier 1 UAV.

It is required that the E-field sensor output be insensitive to rotations, e.g., a scalar sensor or summed vector sensors would be possible approaches. Rotational rates are in the 0.1-1 degree/second range for platforms of interest. The E-field sensor must not create magnetic noise greater than 10 picoTesla per root Hertz (pT/RtHz) in the magnetometer when placed at a distance of one foot away. It is likely that there will be E-field noise arising from the platform itself, which will need to be mitigated. This should be achieved without any modification to the aircraft and without shielding that would remove the signal, so it is likely that a software solution will be required.

PHASE I: Determine the required sensitivity of the E-field sensor so it can correlate with magnetic noise at the 10 pT/RtHz level in the 10 milliHertz (mHz) - 100 Hertz (Hz) band. This may be done either by theory or experiment. Demonstrate the feasibility of the proposed E-field sensor design, which can be used aboard an airborne platform, with the required sensitivity.

PHASE II: Develop an E-field sensor prototype based on the results of the Phase I. Demonstrate the prototype sensor aboard an airborne platform jointly with a magnetometer of the required scalar sensitivity, to measure correlation and effectiveness of the E-field sensor in reducing geomagnetic noise. Demonstration can be done on any aircraft chosen/available to the proposer, but the prototype sensor must be able to fit in a Tier 1 UAV: this restricts the size to tens of cubic decimeters, weight to about a kilogram and power to tens of watts.

PHASE III: Productionize E-field sensor hardware and mature algorithms. Assist in obtaining flight clearance for use on NAVAIR UAV. Develop manufacturing and commercialization plans. Transition sensor to appropriate Navy Tier 1 UAV platforms.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Oil and mineral exploration over the ocean also have the problem of geomagnetic noise and would benefit from such an E-field sensor.

REFERENCES:
1. Renno, N., Kok, J., Kirkham, H., & Rogacki, S. (2008). A Miniature Sensor for Electrical Field Measurements in Dusty Atmospheres. Institute of Physics. Retrieved from: http://deepblue.lib.umich.edu/bitstream/handle/2027.42/64202/jpconf8_142_012075.pdf?sequence=1

2. Dodle, F., H. Fedder, T. Nöbauer, F. Rempp, G. Balasubramanian, T. Wolf, F. Reinhard, L.C.L Hollenberg, F. Jelezko, and J. Wrachtrup. (2011). Electric-field Sensing Using Single Diamond Spins. Nature Physics. Retrieved from: http://www.nature.com/nphys/journal/v7/n6/pdf/nphys1969.pdf

3. Zeng, R., Wang, B., Yu, Z., Niu, B., Hua, Y. (2011). Integrated Optical E?-field Sensor Based on Balanced Mach–Zehnder Interferometer. Optical Engineering. Retrieved from: http://opticalengineering.spiedigitallibrary.org/article.aspx?articleid=1158454%20&journalid=92

4. Bordovsky, M. (1998). Electrooptic Electric Field Sensor for DC and Extra-low-frequency Measurement. Brunel University Research Archive (BURA). Retrieved from http://bura.brunel.ac.uk/handle/2438/4957

5. Sedlacek, A., Schwettmann, A., Kübler, H., & Shaffer J.P. (2013). Atom-Based Vector Microwave Electrometry Using Rydberg Atoms in a Vapor Cell. University of Oklahoma, Department of Physics and Astronomy. Retrieved from: http://www.researchgate.net/publication/256097508_Atom-based_vector_microwave_electrometry_using_rubidium_Rydberg_atoms_in_a_vapor_cell

6. Griffiths, D. (1999, January 9). Introduction to Electrodynamics. Addison Wesley; 3rd Ed.

7. Kraichman, M. (1977). Electromagnetic Background Noise in the Ocean Due to Geomagnetic Activity in the Period Range 0.5 to 1000 Seconds. Naval Surface Weapons Center, White Oak Laboratory. Retrieved from: http://www.dtic.mil/dtic/tr/fulltext/u2/a040922.pdf

KEYWORDS: Airborne; Magnetometer; E-field; Anti-Submarine Warfare (ASW); Geomagnetic; Noise

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T005 TITLE: Innovative Physics-based Modeling Tool for Application to Passive Radio Frequency Identification System on Rotorcraft

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

OBJECTIVE: Develop an innovative, simple-to-use, low cost and computationally efficient tool that can maximize the accuracy and reliability of the onboard Passive Radio Frequency Identification (pRFID) tag/reader antenna system used to track rotorcraft dynamic components in an enclosed multipath metallic rotorcraft environment.

DESCRIPTION: The use of an on-board pRFID tag/reader antenna system provides the ability to track accurately, in near real-time, various serialized parts/components/assemblies after they have been installed on Fleet aircraft. Information gleaned from the tags will enable health and usage monitoring (HUM) of life-limited parts. It will also enhance configuration management control, complete and accurate repair, and maintenance history, while lessening the workload burden on Fleet personnel. As a result, the fast maintenance turnaround can translate into improved aircraft availability and lower life cycle costs. Multipath radio frequency (RF) propagation characteristics in the rotorcraft environment are complex. Some components will be within metallic enclosures adding to the complexity of a system design. A significant loss in pRFID tag read range is to be expected in the rotorcraft environment due to large broadband noise caused by a plethora of surrounding electromagnetic sources. The antenna signal may also come from multiple paths due to reflections from metal enclosures, obstacles or tightly packed bodies thereby causing destructive interference and signal fading. Furthermore, the data transmission effectiveness for the pRFID system is severely limited as a result of a lack of supplied power and attenuation.

In the rotorcraft environment, it is important to understand the RF propagation in a variety of multiple connected, confined, reflective spaces for evaluating the RF reader antenna coverage, RF signal path and tag readability (signal response). The free-space characteristics of a pRFID tag performance changes drastically by the host rotorcraft environment as well as by the surface on which the pRFID tag is mounted. Thus, not only may pRFID properties (e.g. read range, volume coverage) be affected, but also the performance of signal processing algorithms that rely on an assumed behavior of the pRFID. It is imperative, then, to be able to predict the behavior accurately for a given pRFID tag in its actual installation and expected operational environment, rather than just in free space.

Finding an optimum pRFID tag/antenna reader system arrangement without a physics-based model would require numerous time consuming and labor intensive trial-and-error measurements, involving different positions of reader antenna and tag configurations, which can vary significantly with only a slight change in the relative location, position or orientation of the antenna. If the metallic environment of the rotorcraft is simple, then various commercially available physics-based computational electromagnetics (CEM) codes could be used for such analysis. However, this is impractical for a complex electrically large metallic environment coupled with extremely low power transmittance.

We are seeking an innovative, physics-based, low cost, simple-to-use, and computationally efficient tool to provide accurate field predictions (both near and far field) of the total radiated electric field from various pRFID tags at reader-antenna locations. The tool should also aid in the optimal design and placement of the reader-antenna considering multi-path effects, various constraints and the expected operating environment of a rotorcraft.

PHASE I: Develop and demonstrate the feasibility of a physics-based modeling tool for efficiently and accurately predicting effectiveness of pRFID operations on large rotorcrafts in complex environments. Effort will also investigate the formulation of the tool for determining the optimal placement of a reader-antenna for effective and reliable tag readability for a given system configuration.

PHASE II: Fully develop the methodology selected in Phase I and incorporate it into a prototype tool which includes a suitable graphical user interface (GUI). Demonstrate the accuracy, robustness and computational efficiency of the tool.

PHASE III: Finalize the design and generate a fully functional modeling tool ready for integration and operational testing, and conduct performance validation and verification. Transition the modeling tool into a commercially available software product for use in rotorcraft by government agencies and industry.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The tool can be used to optimize pRFID tag systems for health and monitoring of parts needed for complete and accurate maintenance and repair as well as configuration management control on both commercial and military helicopters.

REFERENCES:
1. Jin, J. & Riley, D. (2009). Finite Element Analysis of Antennas and Arrays, John Wiley & Sons.

2. Nagel, J. R., Richards, A. M., Ananthanarayanan, S., & Furse, C. M. (2008). Measured Multiuser MIMO Capacity in Aircraft.

3. Bekkali, A. & Matsumoto, M. (2009). RFID Indoor Tracking System Based on Inter-Tags Distance Measurement, Wireless Technology, Lecture Notes in Electrical Engineering, Springer Science, 41-62.

4. Becker, B., Huber, M., & Klinker, G. (2008). Utilizing RFIDs for Location Aware Computing, Ubiquitous Intelligence and Computing 5th International Conference Proceedings, Oslo, Norway, Springer, 216-228.

KEYWORDS: Antenna; Computational Electromagnetics; Multipath; Rfid; pRFID; signals

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T006 TITLE: Pseudospectral Optimal Control for Flight Trajectory Optimization

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a software application that applies pseudospectral optimal control theory to guided aerial vehicle applications such as missiles, bombs, targets, and unmanned aerial systems for the purpose of optimizing system performance within given constraints.

DESCRIPTION: Any flying vehicle has a limited amount of energy with which to perform its mission, whether it is an air defense missile maximizing range and terminal maneuverability, a guided bomb maximizing speed at impact, or an unmanned aerial vehicle maximizing endurance on station. A common challenge for these systems is developing guidance algorithms that manage the energy to achieve maximum kinematic performance within various constraints on the vehicle's size, weight, payload, cost, or other factors. Changing warfighter requirements also often bring needs for longer range, enhanced maneuverability, or trajectory shaping for survivability. Further compounding these difficulties is budget pressures that demand making do with existing systems and adapting them to meet evolving needs instead of developing entirely new weapons, targets, or unmanned aerial systems (UAS).

Recent developments in optimal control theory may provide a significant technology to address these challenges. Optimal control has long been an attractive means of developing algorithms to maximize flight performance. However, until recently the theory was difficult to apply in practice because of the computation time needed to search the space of possible solutions. New mathematical breakthroughs and today’s computation power offer the potential of practical solutions that can be used real time aboard guided vehicles. Approaches such as the pseudospectral optimal control method have been demonstrated on spaceflight applications and show considerable improvements in optimizing energy management to achieve vehicle maneuvers. The goal of this effort is to extend these techniques to the more challenging non-linear dynamics of atmospheric flight.

The purpose of this topic is to develop a software application that applies optimal control methods to the autopilot of an unmanned guided aerial vehicle (such as a weapon, target, or UAS) in real time. The optimization method will be integrated with a generic but representative autopilot and set of guidance algorithms. The integrated algorithms will be tested and implemented in a hardware test environment to provide a real-time guidance solution for the vehicle. Such a solution obviates the need for methods such as pre-stored lofting tables or a multi-phase guidance implementation (i.e., boost/midcourse/terminal). The software provided shall demonstrate the capability to optimize trajectory characteristics such as: launch envelope, range, time on target, terminal velocity, terminal g-capability, impact angle, and trajectory shaping.

The implementation must allow for re-computable solutions to address physical phenomena that vary over the course of a flight, such as changes in wind speed and direction or thrust misalignment induced by a rocket motor. The algorithmic solution must be fast enough to re-compute the guidance solution at five times the time constant of the guidance and control system.

PHASE I: Develop a conceptual design for a pseudospectral optimal control solution method applicable to a generic guided aerial vehicle that can feasibly run real time onboard the vehicle.

PHASE II: Develop prototype optimization software in an all-digital six degree of freedom simulation environment that demonstrates real-time computational ability to perform the following tasks: (1) increase the launch acceptable envelope, (2) provide simultaneous arrival time on target (through platform pre-coordination), (3) increase standoff range by computing optimal loft trajectory, (4) optimize terminal conditions to achieve a desired range of impacts angles or speeds or g-capability, and (5) re-compute the optimal trajectory solution for flight path deviations experienced after launch caused by phenomena such as winds or thrust misalignments induced by a rocket motor.

PHASE III: Demonstrate integrated performance of the optimal control solver on guidance and control hardware via software-in-the-loop (SWIL) or hardware-in-the-loop (HWIL) simulations. Successful completion of this task should demonstrate maturity to transition to a program of record.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: This technology can also be employed to advantage in any application requiring autonomous operation, such as robotics, unmanned aerial ground vehicles, and spacecraft.

REFERENCES:

1. Fahroo, F. & Ross, I. M. (2008, August). Advances in pseudospectral methods for optimal control. Proceedings of the AIAA Guidance, Navigation, and Control Conference. Paper number AIAA 2008-7309. Paper presented at AIAA Guidance, Navigation, and Control Conference 2008, Honolulu, Hawaii. Retrieved from http://www.elissarglobal.com/wp-content/uploads/2012/04/Advances-in-Pseudospectral-Methods-for-Optimal-Control.pdf

2. Ross, I. M. (2006). Space trajectory optimization and L1-optimal control problems. In Gurfil, P. (Ed.), Modern astrodynamics (pp. 155 188). Oxford, UK: Elsevier Ltd.

3. Fahroo, F. & Ross, I. M. (2002). Direct trajectory optimization by a Chebyshev pseudospectral method. Journal of Guidance, Control, and Dynamics, Vol. 25, No. 1, 160–166.

4. Benson, D.A., Huntington, G.T., Thorvaldsen, T.P., & Rao, A.V. (2006, November–December). Direct trajectory optimization and costate estimation via an orthogonal collocation method. Journal of Guidance, Control, and Dynamic, Vol. 29, No. 6, 1435–1440.

5. Rao, A. V., Benson, D. A., Darby, C. L., Patterson, M. A., Francolin, C., Sanders, I., & Huntington, G. T. (2010, April–June). Algorithm 902: GPOPS, a matlab software for solving multiple-phase optimal control problems using the gauss pseudospectral method. ACM Transactions on Mathematical Software, Vol. 37, No. 2, Article 22, 22:1-22:39.

KEYWORDS: Optimization; Weapon; Guidance and Control; Optimal Control; Trajectory Shaping; Missile

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T007 TITLE: <u>Real-Time Additive Manufacturing Process Models Applied to Wire Fed Electron Beam Processed 4340 Steel</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop innovative, integrated additive manufacturing (AM) structure, processing, and property-geometry modeling concepts that will facilitate the qualification and certification of AM-fabricated 4340 steel alloy parts and enable their rapid deployment.

DESCRIPTION: There has been much progress during the past few years with the advancement of AM techniques. There has been much progress during the past few years with the advancement of AM techniques. Multiple processing techniques are being developed to produce metallic parts. It is anticipated that some of these techniques, if properly engineered, could be used to produce parts that enhance aircraft performance and operational readiness while reducing sustainment costs. This tool-less, on-demand manufacturing technology will facilitate rapid overhauling, servicing, and repair of desired components.

In order to produce parts that can be used on Navy aircraft they must obtain flight certification. To accomplish this, the material properties of the parts manufactured using AM must be fully understood and repeatable to meet flight qualification and certification requirements. Specific concerns include the microstructure and properties of the AM parts, which involves the development of process-microstructural models, sensor technology, and control methods and algorithms.

AM is a uniquely complex process of layer-by-layer deposition. During this process, the thermal history of a layer may involve multiple re-melt and solidification cycles as well as multiple solid state phase transformations. Melt pool size and shape are features that should be controlled in order to produce materials of consistent quality. Beuth and Klingbeil (Ref 1) have developed process maps for predicting melt pool size and related these properties to deposition rate and laser power for the Ti-6Al-4V alloy. By doing so, it was shown that it is possible to maintain a constant melt pool size over a range of deposition rates. The microstructural evolution of Ti-6Al-4V has been investigated and modeled for a variety of AM and thermal mechanical processes (Ref 2). The combined effect of rapid solidification, directional cooling, and phase transformations induced by repeated thermal cycles has a profound influence on the microstructures of the materials deposited. Rapid solidification reduces elemental partitioning and extends solid solubility and can result in metastable phase formation. Directional heat extraction may result in preferred directionality in grain growth. Repeated thermal cycles have a possible complex set of effects, including microstructural banding, i.e., microstructural differences between depositions layers (Ref 3). Thus, in order to rapidly transition this technology, the development of validated models is needed to accurately predict the structure and properties of the 4340 alloy deposit throughout the wire feed electron beam AM process.

The proposed modeling software should be able to predict real-time melt pool size, thermal history in the build, microstructures resulting from rapid solidification, and related mechanical properties at any location in the build corresponding to various process parameters. The software package should include modeling of melt pool dimensions (e.g., diameter and length/depth) and temperature (e.g., melt pool and substrate) throughout the build process in terms of machine parameters such as beam energy, stand-off distance, bead spacing, and build travel speed. Issues with current metallic AM techniques will be identified and included in the software package.

PHASE I: Define and develop a concept for innovative real-time process models for AM of 4340 electron beam wire feed materials. Demonstrate the feasibility to monitor and model the fabrication process and predict the resulting material microstructures and mechanical properties of the fabricated materials.

PHASE II: Develop a prototype control system based upon the modeling and monitoring demonstrated in Phase I. Demonstrate ability to predict the melt pool size and temperature profiles, to fabricate parts using 4340 material with properties equivalent to parts forged with 4340 alloys.

PHASE III: Further improve the software to accurately predict the microstructure and mechanical properties by producing various parts and verifying if the produced properties match with the design requirements. Transition the control system/software package to Navy depots or commercial companies for producing aircraft parts.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: These new approaches can be used for production of large commercial aircraft and other facilities.

REFERENCES:
1. Beuth, J. & Klingbeil, N. (2001). The role of process variables in laser-based direct metal solid freeform fabrication. Journal of the Minerals, Metals & Materials Society, 53, 36–39. doi: 10.1007/s11837-001-0067-y

2. Kelly, S.M. & Kampe, S.L. (2004). Microstructural evolution in laser-deposited multilayer Ti-6Al-4V builds: Part II. Thermal modeling. Metallurgical and Materials Transactions, A, 35A, 1869–1879. doi: 10.1007/s11661-004-0095-7

3. Murr, L.E., Martinez, E., Gaytan, S.M., Ramirez, D.A., Machado, B.I., Shindo, P.W., Martinez, J.L., Medina, F., Wooten, J., Ciscel, D., Ackelid, U., & Wicker, R.B. (2011). Microstructural architecture, microstructures, and

mechanical properties of a nickel-base superalloy fabricated by electron beam melting. Metallurgical and Materials Transactions, A, 42A, 3491–3508. doi: 10.1007/s11661-011-0748-2

4. United States Navy. (2014, February). Naval aviation vision 2014-2025, 25. Retrieved from http://www.navy.mil/strategic/Naval_Aviation_Vision.pdf

KEYWORDS: Direct Digital Manufacturing; Additive Manufacturing; Metallic; Electron beam; process modeling; 4340 alloys

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T008 TITLE: <u>In Situ, Nondestructive Inspection During Additive Manufacturing of Metallic Parts</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop an in situ, nondestructive inspection and monitoring method able to identify material defects for additive-manufactured, metallic parts during the build process.

DESCRIPTION: Additive manufacturing (AM) has the potential to provide rapid production of critical parts for Navy aircraft. However, the final material properties and defects in parts are not as well understood for AM parts as they are for traditionally manufactured forged, cast, and machined parts. These properties are highly dependent on parameters like part geometry, build path, cooling rate, etc. and are difficult to qualify.

Parts manufactured using traditional machining methods and heat treatment processes have been correlated to vast amounts of physical test data to establish material properties and statistically justified confidence bands for those properties. Detection of physical defects is done through multiple inspections throughout the manufacturing process to yield parts that have been 100 percent inspected for all physical defects that might be in the parent material or created by the manufacturing process. Direct (additive) manufacturing machines do not afford the same opportunities to inspect the raw material as a plate, sheet or bar, or, to inspect the raw forging before final machining. Parts are made from wire or powder in a single process and the final net-shape part is more difficult to inspect than those made with conventional manufacturing techniques.

One approach to qualifying an AM part's suitability for use is to destructively evaluate a significant number of parts and measure the properties of interest and look for defects in the part. Typically, this approach also requires statistical sampling of parts for destructive testing to verify the process is still operating correctly. This is costly and time consuming and it negates some of the benefits of being able to rapidly produce different and new parts with this method. It also yields a certain amount of uncertainty that is inherent and any sampling approach to ensuring quality control. Traditional nondestructive inspection (NDI) methods can be used on the finished parts, but more often than not, it is not possible to get 100 percent coverage in these inspections due to the complexity of the geometry that can be obtained by AM. A replacement or supplemental final inspection of an AM part with one or more nondestructive, non-contact inspections that can be done concurrent with the AM build process is needed. Real-time inspection of a part as it is being manufactured will greatly reduce the amount of material that needs to be inspected and could even enable immediate correction of manufacturing defects.

This STTR is aimed at developing an inspection and monitoring method that can inspect and collect data during the build process. This approach to inspection will allow each layer to be inspected before the next layer is built on top of it. The final inspection system should, at a minimum, be able to detect physical defects that would be common to that AM process. Typical physical defects might include problems like porosity and lack of fusion. The ideal inspection system should not only be able to detect physical defects, but also capture information that can be used to accurately estimate material properties of the final part. For example, microstructural changes in the part (like grain size or grain orientation) might be estimated by monitoring parameters like the size, temperature and cooling rate of the melt pool. Eventually, it is envisioned that the system would be part of a feedback loop that helps correct the AM process as the build progresses to optimize build parameters and “prevent” these defects from materializing and to detect and repair defects before depositing the next layer.

The goal of the system is to collect information about all of the characteristics of the deposited material as it is deposited and before it is buried in an un-inspectable location in the part. Such a system will likely need to rely on multiple modes of data collection. Combinations of thermography, laser ultrasonics, eddy current, and/or other non-contact inspection techniques may allow this goal to be reached. The AM processes to be considered for this STTR are electron beam AM and laser-sintered powder bed AM processes. The materials of interest are Ti-6Al-4V or PH17-4 stainless steel. The effort should focus on a single AM process/material combination.

PHASE I: Provide proof of concept for proposed NDI process to detect and quantify possible AM process-induced defects such as lack of fusion and micro-porosity associated with that AM process/material. Consideration should be given to the AM process environment (i.e. inert atmosphere, high temperatures, etc.). Evaluate NDI method for applicability to the potential defects and characterizing material properties with minimal impact on the AM process and determine feasibility for incorporating the proposed NDI process into the selected AM process.

PHASE II: Construct a prototype inspection system that collects the data during the AM process based on the concept from Phase I. Demonstrate ability to collect the appropriate data during the AM build to model material properties and defect locations in the part. Include the development of a physics-based model that correlates the data collected with changes in the NDI response to a defect in the AM test parts. Validate models though additional test coupons, followed by destructive testing and metallography.

PHASE III: Refine system hardware and modeling software to maximize system utility. Identify limitations of the inspection system and probabilities of detection for critical defects. Use the defect model to identify pass/fail criteria for a general AM construction if given a strength or fatigue requirement. Investigate integrating the system into the process controls of the AM machine to correct defects on the fly. Prepare technology for military and commercial transition.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: AM is of wide interest across many industries and throughout the world. Quality control of AM parts is a critical component for facilitating the transition of AM into critical applications. This technology is expected to be of interest to many commercial industries, including aerospace, automotive, and medical.

REFERENCES:
1. Frazier, W. (2014). Metal Additive Manufacturing: A Review. ASM International Journal of Materials Engineering and Performance, 23(6), 1917-1928.

2. Liu, S., Liu, W., Harooni, M., Ma, J., & Kovacevic, R. (2014). Real-time monitoring of laser hot-wire cladding of Inconel 625. Optics & Laser Technology, 62, 124-134.

3. Gu, D., Meiners, W., Wissenbach, K. & Poprawe, R. (2012). Laser additive manufacturing of metallic components: materials, processes and mechanisms. International Materials Reviews 57, 3, 133-164.

4. Kruth, J.P., Mercelis, P. & Van Varenbergh, J. (2005). Binding mechanisms in selective laser sintering and selective laser melting. Rapid Prototyping Journal, 11(1), 26.

KEYWORDS: Porosity; Additive Manufacturing; defects; lack of fusion; inclusions; in situ nondestructive inspection

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T009 TITLE: <u>Towed Magnetic Anomaly Detection (MAD) Aerodynamic Modeling for Rotary Wing Platforms</u>

TECHNOLOGY AREAS: Air Platform, Sensors, Electronics

OBJECTIVE: Develop and validate aerodynamic models and dynamic simulations of Towed MAD systems from rotary wing aircraft.

DESCRIPTION: Magnetic Anomaly Detection (MAD) systems are used on U. S. Navy airborne Anti-Submarine Warfare (ASW) platforms to detect and track submerged submarines. Normally fixed wing platforms such as the P-3C and its predecessors use an inboard MAD system in a non-magnetic tail boom or stinger to help isolate the aircraft magnetic noise from the sensor. Rotary wing platforms, such as the SH-60B and predecessors, tow the magnetometer approximately180 feet from the aircraft in a non-magnetic tow body, to isolate the sensor from the aircraft magnetic noise. Currently, NAVAIR is proposing the integration of towed MAD systems on MQ-8C Fire Scout and MH-60R/S. The possibilities for a MAD sensor include a sensor similar in size and weight to the ASQ-81 used on the SH-60B and much smaller magnetometers that only weigh a few pounds. There are expressed concerns because these tow bodies are so light and will have minimal drag that they will be adversely affected by the rotor wash when near the aircraft during launch and retrieval causing unstable flight which could damage the tow body and/or aircraft and may trail dangerously close to the tail rotor.

There has been much research on towed decoys from fast moving fixed wing platforms such as the F-18 (see references), but very little on towed bodies from rotary wing platforms which are much slower and the rotor wash can affect the tow body when it is near the helicopter. Additionally, the MAD sensor requires much more stable flight compared to the towed decoys in order to reduce the motion generated magnetic noise and thus maximize the detections range. Vertical motion and pendulum motion of the tow body (magnetometer) in the Earth's field creates magnetic noise as well as attitude (Roll, Pitch & Yaw) changes and vibration. The ASQ-81 is not as sensitive as today's state-of-the-art technology, and motion noise was not a major issue. The state-of-the-art magnetometers are more than 100 times more sensitive than the ASQ-81 so this motion generated noise needs to be reduced as much as possible. The stability goal of the towed body, when the towing aircraft is straight and level at constant airspeed, is to maintain attitude (Roll, Pitch and Yaw) within 0.5 degrees and altitude changes to less than 1 foot. Second order effects such as strum on the cable and helicopter vibrations telegraphing down the cable, can cause magnetic noise on the sensor which can also reduce the Signal-to-Noise Ratio; thus, detection range should also be investigated and modeled to determine the vibration and acceleration effects on the tow body.

The model should include input variables such as:
• Tow Bodies: ASQ-81 size (7 inch (") diameter, 60" long, 24" diameter drag skirt, Center of Gravity Towed, 30 pound sensor (lb) weight) and next generation magnetometers (2" diameter, 18" long, 4 lb weight estimated)
• Tow Body Design: Combinations of Center of Gravity towed, nose towed, drag skirt, cruciform tail, and aerodynamic wings and other passive designs that may improve stability.
• Tow Cable: Nominal 0.125 to 0.25 inch jacketed cable, smooth jacket and modified jacket to reduce strum. Magnetometers require power and return (10 – 28 watts @ 28 VDC) and Ethernet (copper or fiber-optic)
• Tow Cable Length: 180 to 300 foot from tow aircraft
• Airspeed: MQ-8C (Bell 407) and MH-60 operational envelope (Approximately 60 – 120 Knots (Kts))
• Aircraft Tow Point: Under-slung or outboard pylon

The model should simulate and determine:
• Roll, Pitch and Yaw stability (PSD from 0.05 to 10 Hertz (Hz))
• Vibration (XVZ Accelerations, PSD from 0.05 to 100 Hz)
• Damping or pendulum motion (When the helicopter comes out of a turn, determine how long it takes to tow body to return to straight and level flight).
• 3 Dimensional position of tow body relative to the aircraft at the airspeed range listed.
The goal of the MAD towed body design is when the helicopter is in straight and level flight to maintain attitude (Roll, Pitch & Yaw) to within 0.5 degrees, altitude change less than 1 foot, and to damp out pendulum motion as quickly as possible, and to reduce any cable strum or vibration interaction with the tow body.

PHASE I: Determine feasibility of proposed methodology to model and simulate the towline shape, towed body 3 dimensional position relative to the tow aircraft, and tow body stability during deploy, recovery and fully deployed for various size tow bodies, tow lengths, cable diameters, cable outer jackets and tow speeds. The algorithms should also determine the drag (weight) at the aircraft and any airspeed related instability in order to size the reeling machine accordingly.

PHASE II: Develop prototype algorithms and demonstrate simulations on various configurations of tow bodies, cables, cable lengths, tow speeds, and aircraft attachment points. Through simulation, determine the most stable design(s) within Size Weight and Power (SWaP) and tow requirements. Construct non-magnetic tow body or bodies and perform wind tunnel and flight tests to validate the design and refine algorithms.

PHASE III: Partner with Towed MAD system developers to provide design and stability data of the Towed body assist, with wind tunnel and/or prototype flight tests. Validate and refine algorithms based on wind tunnel and flight tests. Work with helicopter and Towed MAD System primes and NAVAIR to provide data for flight safety qualification and testing.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The geophysical community uses towed magnetometers for geophysical research and mapping. These algorithms could be used to refine the design of the towed system to improve performance and update the towed magnetometer systems to the much smaller units currently being developed.

REFERENCES:
1. Barnes Jr., B., & Pothier, J. (1971, June). Wind Tunnel Measurement of Airborne Towed Cable Drag Coefficients. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH. Retrieved from: http://www.dtic.mil/dtic/tr/fulltext/u2/754889.pdf

2. Richardson, T., (2005, June). Parametric Study of the Towline Shape of an Aircraft Tow Decoy. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH. Retrieved from http://thehuwaldtfamily.org/jtrl/research/Aerodynamics/Parametric%20Study%20of%20Tow%20Line%20Shape%20of%20an%20Aircraft%20Decoy,%20Thesis,%20Richardson.pdf

3. Leijonhufvud, M., Lindberg, A. (2008). Dynamic Simulation of a Towed Decoy. International Congress of the Aeronautical Sciences. 26th Ed.

KEYWORDS: Tow cable; Anti-Submarine Warfare (ASW); Magnetic Anomaly Detection (MAD); Aerodynamic Modeling; Towed Sensors; Fire Scout MQ-8C; MH-60R

Questions may also be submitted through DoD SBIR/STTR SITIS website.

N15A-T010 TITLE: Powder Metallurgy for Advanced Thermionic Cathodes

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: PEO IWS 2, Above Water Sensors

OBJECTIVE: Develop processes to produce scandium doped tungsten powder for use in the production of advanced high current density thermionic cathodes.

DESCRIPTION: This effort seeks to identify, define (design), and demonstrate a process for the commercial scale production of scandium-doped tungsten powder consistent with the needs of the US domestic cathode industry in meeting Navy requirements. The process is required to provide metal powders with purity, particle size, uniformity and metallurgical content and structure suitable for cathode production and consistent with the latest advances in the field. Process controls that determine metal powder characteristics will be identified and designed into the process. Process repeatability (for consistent quality) will be a paramount consideration, followed in importance by cost and production capacity. The purpose of this effort is to prove a feasible process that will make advanced thermionic cathodes available to the microwave tube industry by providing the constituent metal powders, (not to produce finished cathodes).

Many existing Navy weapon systems rely on microwave vacuum electronics (microwave tubes) as the primary source of Radio Frequency (RF) power. This is especially true for many radar and electronic warfare (EW) systems. Future RF sensors, especially millimeter-wave EW systems, will require unprecedented performance in output power and bandwidth. The Navy has ongoing initiatives to develop capability in this frequency band. Proposed solutions based on vacuum electronics demand advanced, high current density cathodes (a collateral benefit is reduced life-cycle cost through improved reliability). Microwave tubes will exist in Navy systems for many decades to come due to two factors: 1) the sustainment of legacy systems, and 2) the deployment of future systems for which size, weight, and power-bandwidth make vacuum electronics the only viable option. The latter case includes future millimeter wave (MMW) sensors that will place extreme requirements on the MMW vacuum electron devices in the areas of electron beam current density, beam quality, and confinement (Ref. 1). In addition, legacy systems are under constant pressure to control life-cycle cost through increased reliability of expensive components. Often, this is the microwave tube.

Microwave tube performance and reliability depend fundamentally on the cathode. The vast majority are thermionic cathodes produced from the sintering of tungsten powder. Recent advances in cathode science have resulted in Scandate cathodes capable of providing extremely high current densities while promising long life due to operation at standard or reduced operating temperatures (Refs.2-4). These cathodes are produced from tungsten powder that has been chemically doped with small amounts of scandium – an element known to enhance thermionic emission. Once technically matured and commercially available, these cathodes will enable new microwave/MMW tube designs and make possible re-engineering of existing devices for enhanced life, leading to overall cost savings.

Research in the area of Scandate cathodes produced from scandium doped tungsten metal powder has been largely aimed at determining the optimum scandium content, metal powder size and sintering times to produce optimum cathode characteristics (mainly high current density). Consequently, metal powder constituents have been produced in extremely small batches (typically less than 10 grams), driven by research objectives. Scant attention has been given to the production of Scandate metal powders in amounts suitable for commercial cathode production where requirements of a few hundred (i.e. 300-500) kilograms of material per year are anticipated. Therefore, in order to make Scandate cathodes available in sufficient quantity, and at the required (and repeatable) quality, innovative methods for the production of scandium doped tungsten powder must be found. It should be noted that, as this is a revolutionary technology, reducing cost is an important, but secondary consideration. However, as a target, a material cost of no more than five times that of existing cathode-grade Tungsten powder is desired).

PHASE I: The company will define and develop a concept for the production of scandium-doped tungsten powder that meets the requirements as stated in the topic description. The company will demonstrate the feasibility of the concept in meeting Navy needs and will establish that the concept can be developed into a useful process for the Navy. Scaled process testing, analysis and modeling will establish feasibility.
The company will define and develop a concept for the production of scandium-doped tungsten powder that meets the requirements as stated in the topic description. The company will demonstrate the feasibility of the concept and will establish that the concept can be developed into a useful process for the Navy. Scaled process testing, analysis and modeling will establish feasibility.

PHASE II: Based on the results of Phase I and the Phase II contract statement of work, the company will develop a prototype process for the production of scandium-doped tungsten powder. The process will be evaluated to determine its capability in meeting Navy requirements for the production of scandium-doped tungsten powder. System performance will be demonstrated through prototype evaluation and modeling or analytical methods. Evaluation results will be used to refine the prototype into a design that meets Navy requirements. The company will prepare a Phase III development plan to transition the technology to commercial use to supply Navy needs.

PHASE III: The company will support the Navy in transitioning the technology for Navy use. The company will refine the production process for scandium-doped tungsten powder according to the Phase III development plan, for evaluation to determine its effectiveness in meeting Navy demand for microwave tubes. The company will support the Navy for test and validation to certify and qualify the process for Navy use and transition the production process for scandium-doped tungsten powder to a production facility for microwave tube cathodes.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The US domestic vacuum device industry supplies microwave tubes for a variety of scientific (fusion research), industrial (microwave heating) and communication (satellite uplink stations) applications. If successful, translation transition of technology developed under this effort to the industry is assured, as commercial and military microwave tubes are produced on the same production lines, using the same processes.

REFERENCES:
1. Li, Lili, et al. “Development of High-Current Sheet Beam Cathodes for Terahertz Sources”, IEEE Trans. Electron Devices 56, May 2009: pp. 762-766.

2. Wang, Yiman, et al. “Development of High Current Current-Density Cathodes With Scandia-Doped Tungsten Powders”, IEEE Trans. Electron Devices 54, May 2007: pp. 1061-1070.

3. Zhao, Jinfeng, et al. “High Current Density and Long-Life Nanocomposite Scandate Dispenser Cathode Fabrication Development of High Current Current-Density Cathodes with Scandia-Doped Tungsten Powders”, IEEE Trans. Electron Devices 58, April 2011: pp. 1221-1228.

4. Zhao, Jinfeng, et al. “Scandate Dispenser Cathode Fabrication for a High-Aspect-Ratio High-Current-Density Sheet Beam Electron Gun”, IEEE Trans. Electron Devices 59, June 2012: pp. 1792-1798.

KEYWORDS: Thermionic cathodes; scandate cathode; microwave tubes; vacuum electronics; powder metallurgy; tungsten metal powder

N15A-T011 TITLE: Low Level Visible-Light Photo Detectors for Laser Range Finding

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

ACQUISITION PROGRAM: PEO IWS 2, Above Water Sensors, AN/SPQ-9B Program Office

OBJECTIVE: Develop a highly sensitive photo detector to improve laser range finding with eye-safe levels of visible laser light at operational distances.

DESCRIPTION: The Navy is seeking to develop a highly sensitive photo detector to improve laser range finding with eye-safe levels of visible laser light at operational distances. Laser range finding is a proven technique, but for distances relevant to a Fleet battle group, the transmitted laser power must be high. This is normally not a problem if the laser wavelength is in the infrared and the power is kept below the thermal damage level. However, operational considerations require that this effort utilize visible wavelengths and the transmitted laser power must be kept below the absolute eye-safe level.

In the future, naval sensors, for example those used by radar and Electronic Warfare (EW) systems, will be networked together to increase performance capabilities well above that of individual sensors acting alone. This is true for sensors located on the same ship and for sensors located throughout a battle group. Effective sensor netting will depend on obtaining precise distances between ships and the ships’ relative velocities (both speed and bearing). Laser ranging is a possible means to obtain and monitor such position and velocity data in real time (Ref. 1). However, shipboard laser systems must be eye safe, especially when the intention is to “target” friendly vessels (Ref. 2). Therefore, laser transmitter power is restricted when used for such purposes and the sensitivity of the receiver becomes the key variable in the system design.

Avalanche photodiodes (APDs) are the most sensitive photo detectors commercially available and lend themselves to this task (Ref. 3, 4). Future operational concepts will require more sensitive laser detection than the current state-of-the-art APDs. Expanding operational coverage and operation in poor conditions will always demand more sensitivity of any such sensor. This effort seeks to develop an innovative photo detector sensor that detects low light level visible laser light with an order-of-magnitude improvement in sensitivity over existing APDs, making the use of laser ranging systems possible at increased operational distances. Without a sufficiently sensitive photo detector, safety concerns will preclude development of a viable system.

The innovative photo detectors must be capable of absolute sensitivity (the lowest incident power level detectable), and fast response times. There are photo detector technologies, such as photo multipliers, which are far more sensitive than APDs; however, they typically have relatively slow response characteristics. The laser range finding systems envisioned as recipients of this technology will employ extremely short pulse modulations with high repetition rates for the basic range finding function, and accommodate embedded communications. These systems will incorporate pulse and amplitude modulation; therefore, rise time, fall time, and linearity are key attributes of photo detectors developed under this effort. Performance must be an inherent function of the device for range detection in real time. Methods that require integration (within a single pulse, or for multiple pulses), specific modulation schemes, or rely on significant post-detection signal processing are not of interest.

Finally, the sensor's detection wavelength is required to be in the visible band for operational reasons and to preclude interference with existing systems utilizing the infrared bands. The minimum threshold for detectable power should therefore be as low as possible to allow the transmitting laser to be eye-safe at the transmission aperture. Although exact measures of utility are hard to quantify, detector operation at 10 km with the eye-safe transmission requirement may be taken as the minimum performance threshold of interest with much farther detection ranges as a goal. In any case, an order-of-magnitude increase in detection performance is the desired result.

PHASE I: The company will define and develop a concept for an improved photo detector sensor for laser range finding that meets the requirements as stated in the topic description. The company will demonstrate the feasibility of the concept in meeting Navy needs and will establish that the concept can be developed into a useful product for the Navy. Device testing, analysis and/or modeling will establish feasibility.

PHASE II: Based on the results of Phase I and the Phase II contract statement of work, the company will develop a prototype photo detector for evaluation. The prototype will be evaluated to determine its capability to meet Navy requirements for a photo detector sensor for laser range finding. System performance will be extrapolated based on prototype device evaluation using modeling or analytical methods over the required range of parameters relevant to range finding over long distances with eye-safe visible lasers in a maritime environment. Evaluation results will be used to refine the prototype into a design that will meet Navy requirements. The company will prepare a Phase III development plan to transition the technology to Navy use.

PHASE III: The company will support the Navy in transitioning the photo detector sensor technology for Navy use. The company will develop a photo detector sensor for laser range finding according to the Phase III development plan for evaluation in order to determine its effectiveness in an operationally relevant environment. The company will support the Navy for test and validation to certify and qualify the device for Navy use.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The device developed under this effort will have multiple uses (for example, commercial, scientific as well as military). Laser range finding is used in a variety of commercial applications such as surveying. Laser measurement of position is used in the construction and scientific instrumentation industries. There will be potential to translate technology developed under this effort to other wavelength bands (infrared) where additional applications are abundant. Additionally, the pulse modulation requirements of this technology make it suitable for various line-of-sight communication applications.

REFERENCES:
1. Ruiz, Antonio Ramón Jiménez and Granja, Fernando Seco "A Short-Range Ship Navigation System Based on Ladar Imaging and Target Tracking for Improved Safety and Efficiency", IEEE Trans. Intelligent Transport Systems 10 March 2009: pp. 186-197.

2. Wilkins, Gary D. "Eye-Safe Free-Space Laser Communications", Proc. IEEE 1996 National Aerospace and Electronics Conf. 2, May 1996: pp. 710-715.

3. Achouche, M, et al. "InGaAs Communication Photodiodes: From Low- to High-Power-Level Designs", IEEE Photonics Journal 2 June 2010: pp. 460-468.

4. Tsng, Chih-Kou, et al. "A High-Speed and Low-Breakdown-Voltage Silicon Avalanche Photodetector", IEEE Photonics Technology Letters 26 March 2014: pp. 591-594.

KEYWORDS: Photo detectors; laser range finding; eye-safe lasers; laser detection; laser pulse modulation; avalanche photodiode

N15A-T012 TITLE: Naval Special Warfare (NSW) Diver Thermal Human Interface

TECHNOLOGY AREAS: Human Systems

ACQUISITION PROGRAM: PMS 340, Naval Special Warfare

OBJECTIVE: Develop highly streamlined and efficient diver worn components, connectors and fluid delivery lines for a wet submersible that provides a source of heated or cooled seawater for operators in extreme ambient undersea conditions.

DESCRIPTION: The Navy needs to improve the human interface to the SEAL Delivery Vehicle (SDV) active thermal systems. To accomplish this, the following three main areas need to be addressed: 1) properties of the diver suit design including improvement of heat transfer from a heat source thereto, 2) improvement in the location, reliability, and operability of quick disconnect umbilical's from the diver to the heating system, and 3) improvement in the thermal performance characteristics of the delivery components that carry the heated/cooled water from the source to the diver and back..

Operation in water that is colder or warmer than thermally neutral temperatures, roughly 91 degrees F, limits exposure time, exercise capacity, function, and cognitive performance of divers. In particular, operating in temperatures extremes at or near 35°F or above 95°F limits performance and risks serious injury. Specialized solutions have been developed to provide thermal control based on circulating liquid through tubes integrated into a flexible suit. The current suit approach to operating in cold water consists of several layers. The first is an undergarment, such as polypropylene knit fabric. Over the undergarment is the tube suit, made of flexible material that incorporates tubing which warm water runs through to maintain the diver's body temperature. On top of the tube suit is an insulation layer to reduce heat loss from the tube suit to the cold water. The outermost layer is a diver dry suit.

Current tube suits and connections to them are bulky, making it difficult for divers to move quickly or comfortably. Thinner layers with better insulation performance are desirable. Furthermore, integration of the tube layer and the insulation layer may further reduce bulkiness. Also, donning and doffing these types of suits is time-consuming, taking up to 45 minutes (Ref 1). Commercial hot water suits have been available for divers working in cold water (Ref 2), such as offshore platforms in the North Sea. However, these suits are not suitable because they are connected to large water heaters on offshore platforms that are capable of heating supply water to 98°F or higher. These large systems supply the hot water to the diver via an umbilical. In these commercial suits, heating water is not recirculated, but is instead vented out through the wrists and ankles of the suits. Electrically heated suits are used in other applications, but raise concerns regarding reliability, safety, and flexibility of the heating elements and are not considered in the scope of this solicitation.

The tube suit was invented by Richard Long (Patent US3449761 awarded in 1969). Recently, a study was done on a tube suit with six separate heating zones (Ref 3). Hot water was circulated through the tube suit and then returned to the heater through an umbilical. This work showed that maintaining temperature (heating and cooling) is possible but at significant power. Prior work based on Thinsulate™ insulation, a 3M product, and Aerogel, a synthetic porous ultralight material derived from a gel showed promise in improving suit thermal characteristics. Similar materials, as well as reflective metallic foils and coatings, may improve the insulation layer. Heat transfer from the tube layer to the diver may also be enhanced with coatings, and the variations of their integration between the layers could improve the performance as well.

Very efficient active thermal systems and suits, for use by tube-suit wearing divers in a wet submersible such as the SEAL Delivery Vehicle (SDV), are needed since the heating system must be located in the vehicle, with stringent size, weight, and power (SWaP) restrictions. In the SDV, up to 8 divers would be connected to a source that circulates hot (~104F) water to them via fluid lines and umbilicals that must be thermally efficient. In addition, diver components must incorporate penetrators and connectors that are wet-mate able and easy to manipulate, especially for and connecting and disconnecting. The umbilicals and penetrators must be positioned to enable both comfort and rapid egress from the vehicle if required.

The guidelines below set some performance goals for these systems based on continuing government tests and studies. These goals are not meant to be all inclusive nor limit innovation.

a. Passive insulation minimum: 1.4 clo (clothing insulation value to ensure "come home" capability should the fluid source be degraded or fail).

b. Maximum fluid heat loss of 250W between the entry to and exit from the diver liquid circulation garment, with a flow rate of .4 gallons per minute at 32 degree F ambient seawater conditions. At this ambient temperature, idealized models estimate 150W is required to maintain diver thermal neutrality (excluding hands and feet) with the remaining heat (100W) lost to the environment.

c. Maximum heat loss of fluid delivery line: 8W per foot with the line submerged in 32 degree ambient seawater and carrying 105 degree F fluid at a flow rate of .4 gallons per minute.

d. Minimize bulk and maximize ease of use.
i) For the diver-worn "suit", this can be achieved through emerging materials, or by integrating the three layers for "current generation" systems (passive, liquid circulating suit and dry suit) into two garments or even one that are less bulky and faster to don/doff.
ii) Connectors: These include the attachment from the fluid delivery line to the umbilical, and from the umbilical to the diver suit penetrator. Suit penetrators should add minimum bulk to the diver, be easy to operate, and reflect consideration for manufacturability. For example, a penetrator that can be released with one "claw"-gloved hand in poor visibility (low light, murky water) and reattached within 30 seconds may be more favorable than a less bulky version that reattaches in half the time, depending on cost and manufacturability.

e. Efficiency: Several areas offer potential for maximizing efficiency of the Human interface and fluid deliver lines. For example:
i) Ability to leverage "tube" patterns in the liquid circulating garment that cover less surface area but deliver the same thermal effect (Ref 3).
ii) New materials and manufacturing techniques such as "dustless" Aerogel materials or encasing methods.

f. Trade off considerations:
i) In general, less efficient but more easily manufactured components will be more desirable than far-off solutions. Time to manufacture is a more important consideration, so "80% solutions" that could reach full production in 24 months are more favorable than "100% solutions" utilizing emerging materials that may not be ready for production for five years. Participants may also choose to present a "phased" approach that presents alternatives for increments that deliver in near and longer terms.
ii) Solutions that consider thermal balance to include extremities will have an advantage over those that do not.

Note: The Naval Special Warfare is in the process of obtaining metrics and feedback for current prototypes under test and will provide those as they become available during the SBIR life cycle.

PHASE I: The company will develop a concept for a comprehensive and efficient human interface to the SDV's emerging thermal system that will provide heated or cooled seawater based on ambient conditions. The company should verify expected thermal performance improvement via modeling and simulation using computerized heat transfer analyses. The materials and combinations of materials should be evaluated for thermally efficient tube suits. The effort also includes the development of concept designs for quick disconnect penetrators that require minimum visibility and dexterity, and evaluate new connection interfaces between the suits and the heating /cooling system. Feasibility will be established by a combination of modeling, documented approaches, design concept review, and an integration approach. No human testing is anticipated for this Phase.

PHASE II: Based on the results of Phase I and the Phase II contract statement of work, the company will build one or more prototype suits and the related interface components to verify performance in a relevant environment under real-world conditions. The prototype will be evaluated by the Navy to determine its capability in meeting Navy requirements for the Diver Human Interface System. This may require human subject testing. System performance will be demonstrated through prototype evaluation and modeling or analytical methods over the required range of parameters to include: Form Fit and Function evaluations; operating pressures of 120psi; operating temperatures of sea water between 35 to 95 degree F; flow-rate of 0.4-0.6 Gallons-per minute. Evaluation results will be used to refine the prototype into a design that meets Navy requirements. The company will prepare a Phase III development plan to transition the technology for Navy use. If human testing is proposed, company must provide production-ready prototypes to the Navy for manned testing at the Naval Experimental Dive Unit (NEDU) and requisite documentation of materials used to fabricate or produce items.

PHASE III: The company will provide support in transitioning the technology for Navy use. The company will develop the suit and related hardware according to the Phase III development plan for full testing and evaluation to determine its effectiveness in operationally relevant environments. The company will also support the Navy for test and validation to certify and qualify the system for Navy use, and build and test several systems for use in actual field conditions and trials.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Commercial divers working in cold water, offshore oil rig environments could benefit greatly from this technology. The technology could be applied to other non-maritime applications where a protective suit is required for mobile or dismounted operations such as bomb squad, disaster recovery, or HAZMAT tasks. The subcomponents for quick disconnect and umbilical connections could be applicable to other systems such as unmanned underwater vehicles (UUV) thermal/cooling systems, ground vehicle and aerial vehicle-based, and human cooling systems.

REFERENCES:
1. Dry Suit Diving: A Guide to Diving Dry By Steven M. Barsky, Dick Long, Bob Stinton; 2006; http://books.google.com/books?id=X8q9ZjJvkH8C&pg=PA23&lpg=PA23&dq=dry+suit+hot+water+tube+suit&source=bl&ots=GXutIPsbzu&sig=1-6kWdHu0ASpOHgc9p2l1_zpC3U&hl=en&sa=X&ei=7tYgU4aIEIiW0QHs6IEg&ved=0CEsQ6AEwBQ#v=onepage&q=dry%20suit%20hot%20water%20tube%20suit&f=false

2. Viking hot water suit (example): http://www.scubacenter.com/scubacenter_onlinestore/hot_water_suits/Viking_Hot_Water_Suit.htm

3. David R. Pendergast, Joseph Mollendorf, “Exercising divers’ thermal protection as a function of water temperature”, Undersea & Hyperbaric Medical Society, Inc., 2011, Vol. 38, No. 2 – DIVER THERMAL PROTECTION, p 127-136

4. DUI Blue Heat suits: http://www.dui-online.com/products/blueheat/

5. DUI hot water suit (example): http://www.dui-online.com/products/hot-water-suits/

6. Battery powered heating (example): http://www.iopinternational.com/core-heating-system-recreational-diving-hs-eo-r4.html

KEYWORDS: Diver thermal improvement; diver thermal umbilical’s; quick disconnect; SEAL Delivery Vehicle (SDV) active thermal; tube suit thermal improvement, diver thermal human interface

N15A-T013 TITLE: <u>Active Transfer Learning for Intelligent Tutoring</u>

TECHNOLOGY AREAS: Human Systems

ACQUISITION PROGRAM: STEM Grand Challenge and Personal Assistant for Life Long Learning - NETC

OBJECTIVE: Develop a novel framework for intelligent tutoring utilizing algorithms that recognize performance on one task to domain separate but related tasks. The goal is to leverage skills across task domains to speed up skill acquisition on new tasks that might require similar sub-skills related to other task domains. The end result will be an algorithm that allows predictions of performance on varying tasks (e.g., How does a strong foundation in introductory electricity influence the learning of diode circuits, microprocessors, or motors?).

DESCRIPTION: Develop efficient, reliable, and robust algorithms for intelligent tutoring that apply previous domain knowledge through crowd-sourcing analytics on separate but related tasks to predict performance and identify knowledge deficient areas on a new task.

Previous research on transfer learning for human populations (Ormrod, 2004) describes the effective extent to which past experiences (transfer source) affects learning and performance in a new situation (transfer target). Similar predictions culled from machine algorithms use estimates of knowledge gained while solving one problem then applying it to a different but related problem (Pan & Yang, 2010). While predicting far transfer has been shown with human populations, it remains difficult utilizing machine learning techniques.

To predict far transfer, an active component might be necessary. Here, crowd sourcing may assist in identifying the amount/type of information that is relevant to transfer. Previous work on Active Transfer Learning methods may be useful in developing an approach to identify what amount/type of information is relevant, and then verify by crowd sourced experts. The algorithm, through interaction with a subject-matter expert (SME), would then transfer that knowledge to increase the efficiency on the learning task.

Tasks (composed of different skills) should transfer to performance on different skills among a variety of tasks and predict performance. The primary benefit of this approach is that it should not require training on disparate tasks. Rather, this approach should allow for training on only those task domains to identify specific skill-based performance. Skill based learning requires a foundation of knowledge and procedures with some level of assessment on completed tasks (for example, this assessment could be obtained from supervisor Personnel Qualification Standards (PQS) sign-offs. This approach promises to develop much more efficient and effective targeted training across different task domains.

PHASE I: Identify the concept and plan for the development of an algorithm that will catalog skills, that can be mapped in a skill-to-task network (shaped by crowd sourcing experts), and used to predicted future performance.

PHASE II: Produce prototype based on Phase I work; validate algorithm of predicted performance. Reliably predict problem areas for new tasks by examining the skill-based performance on known tasks. Crowd sourcing data should exploit current mobile technology. If practical, the algorithm should integrate with existing navy tutoring systems (ONR’s Grand STEM Challenge) in order to determine its accuracy and usefulness.

PHASE III: During Phase III, this algorithm should integrate with tutoring devices and learning management systems that allow operators to hone skill based performance, thereby increasing task based efficiency. These mobile online tutoring devices allow the algorithms to assess student’s abilities and predict areas of requisite skill and efficiency. For example, assume maintenance personnel have a YouTube like library that they can reference for help. System can assess queries and completed repairs (PQS) to build a model of what the student knows and what future tasking would help extend their capabilities. Videos could be accessed that demonstrate procedural errors or visual inspections tasks that assess the quality of the sailor’s skills.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The proposed technology offers many practical private sector commercial uses. Specifically, organizations with large training overhead costs might apply concepts and tools developed under this Algorithm to reduce overall training costs. Further, this Algorithm might be used as a job selection aide, efficiently in identifying, not only skill deficient areas, but also those areas where the individual may not possess the requisite aptitude to perform the task. Thus “select out” individuals that either cannot perform the task or training would simply take too long.

REFERENCES:
1. Ormrod, J. E. (2004). Human learning (4th ed.). Upper Saddle River, NJ, USA: Pearson.

2. Pan, S. J., & Yang, Q. (2010). A survey on transfer learning. Knowledge and Data Engineering, IEEE Transactions on, 22(10), 1345-1359.

3. Raina, R., Battle, A., Lee, H., Packer, B., & Ng, A. Y. (2007, June). Self-taught learning: transfer learning from unlabeled data. In Proceedings of the 24th international conference on Machine learning (pp. 759-766). ACM.

KEYWORDS: Intelligent Tutoring; Active Transfer Learning; Far Transfer; Skills Acquisition; Crowd Sourcing; Training

N15A-T014 TITLE: Aircraft Carrier-based Precision Ship-Relative Navigation Guidance for Aircraft Landing under Emissions Control Conditions

TECHNOLOGY AREAS: Air Platform, Sensors

ACQUISITION PROGRAM: Seabased Automated Landing Recovery System (SALRS)

OBJECTIVE: Design, develop, and demonstrate a ship based landing guidance system that can provide continuous, high integrity, navigation quality range and bearing data for a fixed wing aircraft during landing approach to an aircraft carrier.

DESCRIPTION: Aircraft carriers need a system to provide continuous, high integrity, precision ship-relative navigation (PS-RN) data to manned and unmanned aircraft for automated and reduced pilot workload approach and landing. Under some conditions, it must operate without any radio frequency (RF) emissions. The challenge is to develop an aircraft carrier-based PS-RN system with the following attributes:
1. No RF emissions.
2. Enable all aircraft within a range of 4 nautical miles (nm) and 10 degrees of the final approach path (aligned with ship landing area centerline with a 3.5 degree glideslope) to execute and approach.
3. Primary system and sensor(s) limited to installation on the aircraft carrier. Any aircraft mounted equipment should be small, low power, and easily integrated.
4. Operable in all lighting conditions, from sun aligned with the approach path, to complete darkness.
5. Operable at reduced range in rain and fog.
6. Capable of providing both ship-relative and earth-relative navigation data.
7. Accurate to within at most 1/10 degree in azimuth and elevation, and 1 percent of range.
8. Guidance quality navigation (high integrity, continuous, stable, update rate of 40 Hertz (Hz) or greater).
9. Provides PS-RN guidance all the way to aircraft touchdown on the ship.
10. Optional additional capabilities: ability to pass data to, and receive data from, the aircraft; ability to identify aircraft type and configuration.

PHASE I: Develop a concept design for a ship based PS-RN system that can solve the problem as outlined in the description section. Demonstrate system operation in simulation, using recorded data from aircraft landings. Provide data on system accuracy, integrity, reliability, range, operability in all lighting conditions, performance in degraded weather, and physical layout on the aircraft carrier. Describe trade studies that have been conducted to determine the best hardware and software components.

PHASE II: Continue to refine the Phase I design and develop a prototype PS-RN system. Demonstrate prototype system operation in flight testing using surrogate aircraft at a shore-based airfield. Include as much variation in lighting and weather as is possible during the period of performance. Use a motion platform to demonstrate determination of relative navigation in a ship and earth-oriented frame of reference simultaneously.

PHASE III: Demonstrate system performance via operational demonstrations using Navy carrier based aircraft, at NAWCAD Patuxent River or Lakehurst. Support the Navy in transitioning the technology for Navy use.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: This system could be used as a low cost navigation guidance system for civil aircraft landing at land- based airports. It could also be used for helicopters landing on oil well platforms and for similar aircraft landing applications.

REFERENCES:
1. Mian, Ajmal S., Realtime Visual Tracking of Aircrafts, Proceedings of the International Conference on Digital Image Computing: Techniques and Applications, DICTA 2008, Canberra, ACT, Australia, 1-3 December 2008

2. Sandmann, David; Dyer, John W., Fagan, John E., Alexander, Dean, Visual Aircraft Tracking System for Departures, Instrumentation and Measurement Technology Conference (I2MTC) Proceedings, 2014 IEEE International

KEYWORDS: EO/IR; aircraft; landing; ship; Navy; unmanned

N15A-T015 TITLE: Experimental Noise Measurement System for Ship Sonar Design

TECHNOLOGY AREAS: Sensors, Battlespace

ACQUISITION PROGRAM: Torpedo Warning System (PMS 415); HVU Mounted Sonar FNC (ONR)

OBJECTIVE: Develop portable, self-powered affordable sensors that can be attached to the exterior of a ship for measurement and recording of acoustic noise on the hull.

DESCRIPTION: Hull-mounted sonar systems used on ships and submarines are an important capability for underwater sensing. Placement of the hull-mounted sonar is part of a design process that requires knowledge of the noise characteristics of the vessel. Noise can include the effects of (1) hydrodynamic flow as the ship or submarine moves through the water, and (2) acoustic radiation from the ship transmitted through the water or borne by the hull structure. This STTR topic seeks to develop sensors that can be attached to the exterior of a ship and record noise for at least five days. The sensors must be capable of attachment below the water line without permanent hull modification or requiring dry-dock facilities. This topic also seeks to develop analysis software to examine measurements recorded from spatially sparse sensors and, given the hull shape, estimate the noise experienced elsewhere on the hull.

The Navy seeks innovative and cost-effective solutions for this effort with generic applicability to a wide range of ship hulls. Design solutions tailored to a particular ship will be considered less desirable.

PHASE I: Design, develop and test a single sensor that incorporates acoustic pressure and vector sensor capabilities, an integral power source, clock and recording device. The sensor should be watertight and survivable to depths of 100 feet (ft). Develop algorithms and a preliminary design for noise analysis software.

PHASE II: Design and develop a temporary hull-mount mechanism that attaches the sensor under wet conditions and is survivable to speeds of 25 knots. Produce two sensors based on the Phase I results that incorporate this mechanism and test them on a Navy ship or representative vessel. Develop and test prototype software for analysis of multiple sensor recordings that estimates noise elsewhere on the hull.

PHASE III: Produce complete noise measurement system including multiple sensors, software, installation guidance and operating instructions. The company will perform operational demonstrations of the sensor system and software to ensure it meets Navy requirements. The company will also support the Navy in transitioning the technology for Navy use.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Successful development of this system will enable rapid and cost-effective data collections to support hull sonar sensor placement analyses by industry sonar developers. Additional commercial applications might include noise measurements for acoustic fault isolation of machinery on merchant ships.

REFERENCES:
1. Ross, D., "Ship sources of ambient noise," IEEE Journal of Oceanic Engineering, vol.30, no.2, pp.257-261, April 2005.

2. Takaaki Musha, Akira Shinohara, “Evaluation of ship radiated noise level from near-field measurements, “Applied Acoustics, vol.40, no. 1, pp. 69-78, 1993.

3. Shipps, J.C.; Abraham, B.M., "The use of vector sensors for underwater port and waterway security," Sensors for Industry Conference, 2004. Proceedings the ISA/IEEE, pp.41-44, 2004.

4. Johnson, M.P.; Tyack, P.L., "A digital acoustic recording tag for measuring the response of wild marine mammals to sound," IEEE Journal of Oceanic Engineering, vol.28, no.1, pp.3-12, Jan 2003.

KEYWORDS: Accelerometers; acoustic measurement; bio-communications; data recording; hydrophones; sonar

N15A-T016 TITLE: Hybrid High Ampacity Electric Power Cable

TECHNOLOGY AREAS: Ground/Sea Vehicles, Battlespace, Weapons

ACQUISITION PROGRAM: PMS501-LCS Program

OBJECTIVE: Develop and demonstrate an innovative low loss hybrid electrical power conductor which, under normal operating conditions, functions as a high current density power cable (35 Mega-amperes per square meter (MA/m^2)) greatly exceeding the ampacity through conventional copper cables (3 MA/m^2). During a loss of power to any associated supporting system which enables the high current density of the cable, the cable system remains capable of delivering 30% of the full rated cable current.

DESCRIPTION: Future ship platforms are expected to field electric weapons and sensors with power and energy demands that are much higher than in today’s ships. Improved power distribution technology is needed to meet these demands and support a fully integrated power system which maximizes efficient use of installed power generation. Using conventional copper cables at a specified voltage, higher power electric mission load demands would be met by increasing the number of installed copper cables, thereby increasing the weight of the integrated power system. Today’s budgetary climate forces the Navy to control ship acquisition costs by constraining the overall size/displacement of new ships so that they are no larger (or perhaps even smaller) than today’s ships. The continued use of conventional electrical system implementation methods will limit the amount of power system infrastructure within the machinery spaces (and therefore limit the power available to mission loads), which would likely result in a ship with reduced mission capabilities. Increasing power density of electrical distribution components and cables is necessary to meet power demands of future navy ships.

The objective of this effort is to develop and demonstrate an advanced conductor or power cable technology that greatly exceeds the ampacity limits of conventional copper cables while minimizing associated cables losses. The losses in proposed power cable concepts or supporting equipment should not exceed that of copper conductor equivalent solutions. One potential technology area for consideration is a hybrid high temperature superconducting (HTS) and copper power cable capable of functioning at a reduced capacity in the event of a cryogenic cooling system failure. This configuration would support ship machinery system start-up and shut down operations while also increasing survivability through reduced capacity operation.

Proposed solutions should consider alternate conductor technologies that provide clear advantages in size, weight, gravimetric and volumetric power density, cost, and/or electrical distribution efficiency while considering the impacts of the proposed cable system in an integrated power system environment. Proposed solution topologies may consider voltage in the range of 1-5 kV with a current rating on the order of 2-5 kA. This solicitation is not limiting the cable architecture and concepts of monopoles, dipoles, DC, and AC can be explored. Voltage and current levels outside the suggest range will also be considered.

PHASE I: Define and develop an alternative power conductor or cable technology concept that meets the stated objectives as discussed in the Description section. Feasibility of the proposed concept should be demonstrated through modeling, analysis, and/or bench top experimentation where appropriate. Clear benefits in terms of size, weight, cost, power density, and/or electrical distribution efficiency shall be quantified as compared to a copper cable solution The Phase I final report should clearly capture the feasibility and viability that the proposed concept can be further matured if awarded a Phase II.

PHASE II: Develop and fabricate a prototype based on the Phase I work for demonstration and characterization of key parameters of the cable system. The prototype demonstration should be capable of full scale voltage and current according to the design and relevant testing should be completed to prove the full scale metrics. Based on what is learned through the prototype demonstration, a substantially complete design of a cable system should be completed to allow for Navy qualification testing. This design will include all ancillary equipment required to operate the cable including cable terminations, cryogenic systems, dielectric solutions, etc. when applicable to the proposed concept.

PHASE III: The company will be expected to support the Navy in transitioning the technology for Navy use. This includes teaming with appropriate industry partners to provide a fully qualified power cable for interested acquisition programs.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The desired hybrid electrical power conductor technology has direct applications in commercial power grids, power distribution, electric power conversion, cryogenic power applications, and arctic operations, making it broadly applicable to the commercial world.

REFERENCES:
1. V. Selvamanickam, A. Xu, Y. Liu, N.D. Khatri, E. Galstyan and G. Majkic (University of Houston), C. Lei and Y. Chen (SuperPower), "Correlation between in-field critical currents in Zr-added (Gd, Y)Ba2Cu3Ox superconducting tapes at 30 and 77 K," Superconductor Science and Technology, 27, 055010, March 11, 2014.

2. D.W. Hazelton, "2G HTS Properties Beyond Critical Current," CHATS-AS 2013 Workshop, October 11, 2013, Cambridge, MA, USA.

3. V. Selvamanickam, I. Kesgin, A. Guevara, T. Shi, Y. Yao, Y. Zhang, Y. Zhang, and G. Majkic (UH); Y. Chen, Y. Qiao, S. Sambandam, G. Carota, A. Rar, Y. Xie, and J. Dackow (SuperPower), “Progress in Research and Development of IBAD-MOCVD Based Superconducting Wires,” Applied Superconductivity Conference, August 2, 2010, Washington, DC, USA.

KEYWORDS: Electrical Power Conductor; Power Distribution Transmission; Electric Power Efficiency; Extreme Temperature Operation; Enhanced Performance; Thermal Performance

N15A-T017 TITLE: Graph Grammars for Naval Essential Tasks

TECHNOLOGY AREAS: Information Systems

ACQUISITION PROGRAM: Data Focused Naval Tactical Cloud EC, Distributed Common Ground Station

OBJECTIVE: Develop an innovative graph grammar approach to machine understanding and fulfillment of standard Navy/Marine Corp essential mission tasks that captures relevant conditions and predicts measures of performance.

DESCRIPTION: The transformation of Big Data access to enhanced tactical level decision making remains an unfulfilled vision. While the Naval services maintain conceptional models for missions and the associated essential tasks forces must be able to plan and conduct (1,2), these models are not semantically mapped to a data representation of the conditions that affect measures of effectiveness. Such a mapping is complex given that for each task, there are associated conditions that must be set and measures of effectiveness that must be achieved. Conditions relevant to the conduct of mission tasks include the physical environment, military environment and civil environment (3). The physical environment includes information about land, sea, air and space. The military environment includes information on the mission; forces; Command, Control, Communications, Computers (C4); intelligence; deployment; movement and maneuver; firepower; protection; sustainment; threat and conflict. The civil environment includes information about political polities, culture and the economy. For any force operating in any area, information about conditions relevant to the set of essential tasks can be expressed as a “big knowledge graph”. This graph can be produced by data enrichment capabilities allowed to operate against all available data stores.

This topic will enable the development a capability, using graph grammars, to quickly write a graph transform from a “big knowledge graph” that describes a mission and relevant conditions in a way that enables the calculation of mission measures of effectiveness. These graph transformations may require use of graph grammars to transform a large graph to an embedded space having a much lower graph dimensionality that captures the key nodes/edges relevant to a mission and its conditions(4). A mature product may require a user interface that allows graph transformations to be generated by staffs of commanders at all levels with limited programming expertise. Once a mission is assigned and mapped to an embedded information graph space, that transformed graph then needs to be sent to all reachable information sources (local and reach-back) in order to populate the graph model with information. The use of graph grammars has already been used within the development community for a wide variety of analytic tasks including information retrieval (5), but for this topic, deeper mission semantics will be required. Some of the concepts involved in the definition of missions and conditions will also require innovation in structured grammars beyond the current state-of-the-art in order to specify concepts that involve high order graph structures with time/space/context constraints on nodes/edges. The use of graph grammars for concepts, while not as mature as structured text grammars, is an emerging discipline with a body of prior art (6). Once a mission/condition graph transform is completed, the system also needs to be able to assess graph completeness in order to assess mission readiness and project likely measures of performance.

For Phase I, offerors may use any publically available RDF (data triples) data sets about places containing a large number of edge relationships. One example is U.S. census data which is available at http://datahub.io/dataset/2000-us-census-rdf. To demonstrate progress, the performer may want to assume that a program is planned that intends on improving some aspects of life in communities (e.g. reduce crime, improve economic conditions) and present a logical model about what initial conditions would enhance the predicted measures of effectiveness of the program and what initial conditions would reduce measures of effectiveness. This model should be entered through a user friendly interface and allow subset of the node types to be included in the model. Performers should not use graphs that are completely populated. While performers are free to demonstrate progress in other ways, all Phase I efforts should mature a technical approach to using graph grammar to identify relevant subgraphs and to measure the distance of each from a graph that captures the dependence of measures of effectiveness on conditions. Rya is the preferred triple data store, but other open source or government owned options are acceptable.

The specific technical challenges associated with this topic include: 1) Transform a large and high dimensionality data structure to mission/condition relevant graphs, 2) Use these graph transformations as a means to communicate data needs to distributed information sources, 3) Collapse collected information into a final graph for a mission, and 4) Translate the information content of mission graphs to a set of mission measures of performance.

PHASE I: During the Phase I effort, performers are expected to identify a technical approach consistent with the goal of reducing the technical risk associated with building a working prototype during a Phase II. For a bounded set of missions and conditions, show graph transformation, automated information collection and content assessment. Begin work on mapping specific mission graph content to mission measures of effectiveness. Conclude with a proof of concept demonstration using open source data that shows technical risk retirement. Phase II plans should also be provided to include key component technological milestones and plans for testing and validation of the proposed system and its components.

PHASE II: Produce a prototype system based on the preliminary design from Phase I. The Phase II prototype should support a diverse set of Naval missions and conditions and automate the assessment of mission measures of effectiveness. A Phase II performer will be provided data by the Government. An offeror may assume that the prototype system will need to run as a distributed application in cloud architecture against billion node graphs. Phase II deliverables will include a working prototype of the system, software documentation including a user’s manual and a demonstration involving operational data or accurate surrogates of operational data.

PHASE III: Produce a system capable of deployment and operational evaluation. The system should consume available operational and open source data sets and focus on areas/missions that are of interest to specific transition programs or commercial applications. The final system needs to have an easy to use man-machine interface. The software and hardware should be modified to operate in accordance with guidelines provided by transition sponsor.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Internet search engines would benefit from the maturation of data retrieval based on concept graph grammars. Currently, information retrieval is limited to word searches with some support to graph searches. Information retrieval by subject, delivered without redundancy, would transform information delivery.

REFERENCES:
1. Marine Corps Task List, 1 January 2014. Available at: www.mccdc.marines.mil/Units/MarineCorpsTaskList.aspx

2. Carpenter, J. D., "Using Mission Essential Task Lists as a Basis for Mission-Based Operational Test Planning". Unpublished. Available at: www.dtic.mil/ndia/2007test/Carpenter_SessionD2.pdf

3. OPNAVINST 3500.38A/MCO 3500.26_/USCG COMDTINST M3500.1A 1Oct 2002; Available at: http://www.google.com/url?url=http://www.mccdc.marines.mil/Portals/172/Docs/MCTL/MCTL%2520Conditions.doc&rct=j&frm=1&q=&esrc=s&sa=U&ei=6JotVJrxOOblsAT04IGADQ&ved=0CBQQFjAA&sig2=yjV9fRYq_OXSLNk8fblaBg&usg=AFQjCNFtO-nygA9QbN-DaQjrI5SpbjcjzA

4. Fahmy. H., Blostein D., "A Survey of Graph Grammars: Theory and Applications": Department of Computing and Information Science Queen's University,Kington, Ontario, Cananda: Available at: www.researchgate.net/publication/3513859_A_survey_of_graph_grammars_theory_and_applications

5. Jonyer, I, Holder, L., Cook, D., "Concept Formation Using Graph Grammars": Department of Computer Science and Engineering University of Texas at Arlington: Available at: ailab.uta.edu/old_site/subdue/papers/JonyerMRDM02.pdf

6. Liu, Y. "Graph-Based Learning Models for Information Retrieval: A Survey" Available at: www.cse.msu.edu/~rongjin/semisupervised/graph.pdf

7. Ehrig, H, "Introduction to Graph Grammars with Application to Semantic Networks" Computers Math Applic., Vol., 23, No 6-9, pp.557-572, 1993.

KEYWORDS: Graph Analysis, Graph Grammars, Information Science, Modeling, Predictive Analysis, Human Machine Interface, Concept Modeling

N15A-T018 TITLE: Maritime Local Environmental Sensing for Electromagnetic Maneuver Warfare

TECHNOLOGY AREAS: Sensors, Battlespace

ACQUISITION PROGRAM: PMW-120 non-ACAT Future Metoc Capabilities

OBJECTIVE: The objective of this research is to develop a capability for operational forces to measure the full set of environmental state variables (pressure, temperature, absolute humidity, wind speed and direction, cloud liquid water content, precipitation type and rate, turbulence and aerosol concentrations) remotely from a single fixed position on the exterior decks or mast, at multiple vertical levels from the ocean surface (below deck level) to well above the top of the atmospheric boundary layer to approximately 3500 meters. In addition to the mean state at multiple levels, the vertical gradients of temperature and humidity in the surface and mixed layers are of high interest. A multi-sensor system should be designed that is affordable and maintainable in a maritime environment, fits within surface Navy power and size constraints, and to the extent possible is self-calibrating. The system should be eye, radiation, and noise safe for personnel working in the vicinity in normal operational mode. Successful execution of this STTR would support a proof-of-concept demonstration of an at-sea capability.

DESCRIPTION: The Surface Navy has interest in high fidelity prediction of EM and EO propagation from surface ships to support prediction of radar, electronic warfare, and communications systems operation. Additionally, lower tropospheric winds, density, visibility, icing, and turbulence are needed for marine aviation and higher fidelity observation, and prediction is desired for new platforms such as ship-launched remotely piloted aircraft. Currently, the fidelity of numerical prediction programs is limited in part by the fidelity of the locally observed environmental conditions used as input. This project desires to investigate technologies that would enable high fidelity measurement of environmental profiles in the vicinity of a surface ship. Measurements out to the radar horizon, 360 degrees in azimuth, from an elevation starting at the surface near the ship and extending to 90 degrees, with 1 nautical mile horizontal range resolution, 1 degree azimuth resolution, and 5 meter altitude resolution up to 3500 meters are required with accuracies sufficient to enable construction of high fidelity diagnostic profiles. All designs should include “cut-out” capability to allow placement as possible on ships and only radiating/sensing in directions not interfered with by ship superstructure or personnel.

Technologies of potential interest could include, but are not limited to, Doppler LIDAR and LIDAR spectroscopy, ceilometers, passive radiometry, acoustic sounders, and direct measurement of state variables in an integrated design to produce best possible absolute accuracy and precision. Bulk similarity approaches for more limited direct retrievals such as evaporative duct estimates from sea surface (skin or inlet) temperature, near surface air temperature, relative humidity or wet bulb temperature, mean sea level pressure, and cup-and-vane or sonic anemometer wind speed and direction could be considered only as part of a more general solution to the total vertical profile. To the maximum extent possible, the system should be automated and require minimal maintenance and be self-calibrating. In addition, rapid changes in ambient conditions due to natural changes or ship movement require a relatively rapid measuring capability of no more than 30 minute intervals, with a capability to retrieve a partial set of variables at higher repeat intervals. Accuracy roughly equivalent to a calibrated commercial rawinsonde, but without the use of expendable in-situ sensing approach is desired. Small unmanned aerial vehicles (UAVs) are not considered a feasible approach for this particular topic.

There are a variety of commercial sensors currently used in the Navy to estimate the immediate atmospheric and ocean surface environment surrounding maritime surface vessels. Nonetheless, available environmental monitoring approaches all suffer from various disadvantages with respect to the parameters most needed for Naval operations, such as evaluation and prediction of the Electromagnetic (EM) propagation environment for radars and communication systems, the Electro-optic (EO) environment for imaging sensors, laser weapons, and optical communications, and the lower tropospheric weather conditions for maritime aviation. Traditional Naval surface observations of bulk atmospheric pressure, winds, temperature, visibility and humidity are at a single level such as the main deck or superstructure and do not provide vertical profiles or gradients needed for many applications. Estimates for evaporative duct height and refractivity gradient strength are indirect and rely on empirically-based bulk similarity assumptions that are frequently violated, especially in non-equilibrium background states. Direct profiling systems such as rawinsondes require significant cost, maintenance and logistic support for expendable components. Indirect profiling systems such as passive microwave radiometers suffer from relatively coarse vertical resolution, poor absolute accuracy, and do not provide the full set of variables needed for many applications. Differential Absorption, Raman, Backscatter, or Doppler light detection and ranging (LIDAR) has not been developed to retrieve all needed variables in a form factor suitable for maritime applications.

PHASE I: Define, develop and validate the component modules in a realistic environment, a concept for the determination of 3-dimensional environmental state variables that can meet the vertical resolution, timeliness and accuracy requirements as stated in the Description section. A table of directly measured or derived environmental variables sensed, estimated accuracy, precision, and spatial/temporal resolution should be included. Additionally, an estimated final size, weight, power, and cost per copy based on the Phase I design should be included.

Required Phase I deliverables include a report which defines the concept and provides relevant details that shall include hardware designs, and relevant lab measurements validating the feasibility in terms of size, weight, power, and accuracy of the components for the final design. Additional required Phase I deliverables will include proposed metrics and measurement methodologies, schedule, and cost estimate for Phase II as well as the Phase I Final Report.

PHASE II: Refine, develop, demonstrate and validate the hardware and software designs produced in the Phase I effort into a prototype system. Deliverables from the Phase II effort shall include the prototype hardware and software, and a report that documents the performance of the prototype. The small business will produce a prototype package that works in a shipboard maritime environment. Based on Phase I efforts and any redirection from the program office, Phase II will develop, demonstrate and validate the solution.

Required Phase II deliverables will include:
- Design architecture, algorithms and data analytics
- Test plan
- Software executables and source code
- Demonstration of solution effectiveness and relevance in a representative environment
- Suitable ship time will be provided by the ONR Code 32 Sponsor on a UNOLS Research Vessel proxy. Integration/ installation costs will need to be included in the Phase II budget proposal.
- A prototype system that may be optionally retained by the sponsor for further characterization
- Phase II Final report

PHASE III: Refine the prototype system into a product that can be used on a surface Navy combatant, with appropriate user interfaces, and documentation. At the end of the Phase III effort the system should be at a Technology Readiness Level of 7.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Marine weather observing and forecasting, commercial shipping and navigation, environmental monitoring of remote and minimally attended locations could benefit from this technology.

REFERENCES:
1. J.D. Whalen, March 1998, "Comparison Of Evaporation Duct Height Measurement Methods and their Impact On Radar Propagation Estimates." Retrieved from: http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA345694

2. Evaporation Duct Height. Retrieved from: http://www.nrlmry.navy.mil/refract/evapductht.htm

3. S. Chen, J. Cummings, J. Doyle, R.H. Hodur, T. Holt, C. Liou, M. Liu, A. Mirin, J. Ridout, J.M. Schmidt, G. Sugiyama, and W.T. Thompson, 2003, COAMPS™ Version 3 Model Description--General Theory and Equations, NRL Publication, May, 2003, 145. Available from the Naval Research Laboratory, Monterey, CA, 93943-5502. Approved for public release; distribution unlimited. [NRL/PU/7500--03-448.]

4. J. D. Doyle, F. Giraldo, S. Gabersek, "A Multiscale Non-hydrostatic Atmospheric Model for Regional and Global Applications," ECMWF 15th Workshop on the Use of High Performance Computing in Meteorology, 2012.

5. T. Rogers, Q. Wang, and C. Yardim, "Discrimination Data Sources for Estimating Electromagnetic Propagation," National Radio Science Meeting, 2014.

KEYWORDS: Maritime environmental sensors; environmental remote sensing; electromagnetic refractivity and ducting; marine weather observations; unattended meteorological sensors; LIDAR

N15A-T019 TITLE: Additive Manufacturing Development of Efficiently Cooled Heat Exchangers

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

ACQUISITION PROGRAM: Applied Research Challenge Topic

OBJECTIVE: To explore and mature additive manufacturing (AM) processing via ICME (integrated computational materials (science and) engineering) methodology to develop consistent cellular heat exchangers for improved cooling effectiveness for applications in Naval ships, submarines, and aircraft. The proposed effort should also explore the science base of AM process factors that will lead to development of the evaluation criteria and methodologies to qualify (AM) components across the Naval Enterprise.

DESCRIPTION: As electronic applications multiply and new designs require higher power outputs, more efficient thermal management schemes for cooling are needed to reduce system level costs. As one example, submarines operating in warmer waters have difficulty handling heat dissipation from their electronic systems. Requirements for increased heat rejection from system electronics are wide-spread, existing across the board in Naval ship, submarine and aircraft/missile systems. With the advent of innovative additive fabrication/manufacturing methods, with which complex structures are constructed layer-by-layer, it is now possible to build cellular substrate structures in which flow channels are incorporated within the substrate. There are a number of factors that will contribute to the reliable manufacture of component via AM. Through the use of ICME, AM processes can be evaluated and modified to minimize/eliminate defects through control of process variability. It will also help determine the process window in which acceptable components can be produced by the AM process that will have similar or improved metallurgical microstructures, and physical and mechanical properties when compared to the traditionally fabricated heat exchangers. The integrity and performance of the AM-fabricated heat exchanger compared to the traditionally fabricated HX will be validated by (a) ICME methodologies, (b) mechanical and environment testing of the HX, (c) destructive examination, (d) non-destructive examination the HX, and (e) testing of the heat transfer characteristics.

The initial phases of the program should focus on the AM processing to deliver consistent, qualifiable HXs for Naval applications. In later stages of the program, if funding and time are available, the development work should include integrated models considering fluid flow (pressure drop, effects of turbulence, viscosity, etc.), heat transfer, mechanical and materials properties, as well as innovative additive manufacturing methodology for the fabrication of efficient, low cost cellular ceramic electronics substrate, with highly enhanced heat removal capability.

PHASE I: Using a generic HX CAD file supplied by ONR, employ ICME focused AM methods to replicate a current HX product design (baseline) demonstrating desired properties such as material strength, surface finish, flow integrity (i.e., devoid of defects, leaks or blockages) while maintaining component thermal efficiency with acceptable cost of manufacturing and realistic reliability factors. Laboratory scale specimens should be fabricated and characterized by mechanical testing, and destructive and non-destructive (NDE) evaluations. A framework for involving in-process NDE to improve component integrity should be planned.

PHASE II: Apply ICME tools and processes to AM methods to predict design limits needed to produce a more complex HX product with significant changes in properties such as improved heat transfer, reduced number of parts and joints, that meets the baseline HX "form, fit, and function" constraints while maintaining the physical and mechanical properties outlined in Phase I. Validation of ICME tools and predictive analysis capabilities will be analyzed by comparing the physical, metallurgical and mechanical properties of an AM heat exchanger with a current heat exchanger fabricated by traditional means to validate the production of a heat exchanger by one additive manufacturing process. Initial in-process NDE sensors with feedback control should be tested to determine the degree of AM process improvement. The non-destructive methods will be correlated with destructive examinations. The involvement of a HX original equipment manufacturer (OEM) will be strongly encouraged to participate and assist in developing the pathway for qualifying HXs and components for naval use.

PHASE III: Additive manufactured heat exchangers will be transitioned using funding provided by the Navy system program office for the system evaluated under the STTR program. The OEM involved during Phase II will be part of the transition team. Phase III will include defining the additive manufacturing parameters for qualified full scale system production and establishing facilities capable of achieving full scale production capability of Navy-qualified HXs.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Heat exchangers are universal and employed in numerous commercial systems that reject heat for engines, electronics, and other heat producing devices. The use of AM could lead to more innovative HX designs capable of more efficiently removing heat because such designs could eliminate or severely reduce joints. AM processing of components that are qualified for Navy use could also be applied to commercial use.

REFERENCES:
1. S. Baskutis, V. Vasauskas, “Mechanics and Material Aspects in Serviceability of the Heat Exchangers”, Mechanika, 17 (3), pp. 239-245.

2. B.A. Cowles, D. Backman, "Advancement and Implementation of Integrated Computational Materials Engineering (ICME) for Aerospace Applications," AFRL-RX-WP-TP-21010-4151.

3. W.E. Frazier, "Metal Additive Manufacturing: A Review", Journal of Materials Engineering and Performance, v.23(6) June 2014 pp 1917-1928.

4. M. F. Horstemeyer, "Integrated Computational Materials Engineering (ICME) For Metals", John Wiley & Sons, Inc. 2012.

5. Lu, T.J., 1999, "Heat Transfer Efficiency of Metal Honeycombs", International Journal of Heat and Mass Transfer, Vol 42, No. 11, pp. 2031-2040.

KEYWORDS: Additive manufacturing; heat exchangers; qualification; reliability; thermal properties; mechanical properties; non-destructive evaluation

N15A-T020 TITLE: Bot Detection in Novel Information Environments

TECHNOLOGY AREAS: Information Systems, Sensors, Human Systems

ACQUISITION PROGRAM: CMP-FY15-02 Environment Designed to Undertake Counter A2AD Tactics Training

OBJECTIVE: Detection of "social bots" in social media information streams, to determine their impact on social discourse and characterize their source(s), intents and modes of operation.

DESCRIPTION: Social bots - automated systems for posting information, hijacking accounts and auto-posting for others in social media face or through "robot" (fake) accounts - can be used to influence and manipulate crowds in social media venues (web forums, Twitter, Facebook, etc.) and are currently used to spread messages for a variety of purposes. Many of these bots can be easily detected by existing bot-detection methods; others are more sophisticated. Social bots could be used to spread hate speech, incite crowds to engage in spontaneous violence, and amplify messages for many purposes. Social message attacks on phones through Short Message Service (SMS) messages are another venue of concern. This effort will develop new methods and technologies for detecting social bots; develop methods and techniques for evaluating their impact on social discourse; and develop methods and technologies for evaluating their mode of operation (entirely scripted from one coordinate point, many actors using similar methods, such as a common script and common goals, or many actors who use a variety of methods to manipulate crowds). Disaster and complex humanitarian operations increasingly operate in areas in which civil unrest, terrorist actions, mobbing and other events influenced by disinformation, hate speech, rumor mongering and hysteria propagation using social media pose dangers to human security. This effort will develop techniques to distinguish human from artificial propagation of messages, gauge the communicative reach of disruptive, deceptive messaging, and provide the basis for developing techniques for revealing, countering, and mitigating efforts to promote violent response in complex humanitarian crises.

This affects affordability as current methods of identifying orchestrated efforts to promote violence, hysteria, and deception are primarily done via expensive third-party providers that do not provide sufficient technologies to adequately discover and characterize these flows.

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

PHASE I: Develop designs and prototype code for detecting social bots operating in a variety of information environments, characterizing their behavior, and estimating their impact on target audiences.

PHASE II: Refine initial products into a working prototype of software for detecting artificial and hybrid human-in-the-loop methods of artificially amplifying target messages in multiple strategic languages. Develop advanced techniques for characterizing their purpose, tactics, and typology; establish and test metrics for estimating impact on target audiences.

PHASE III: Incorporate methods to detect evolved and evolving strategies of deception, hate speech, and crowd polarization strategies. Complete the development of technologies to find malicious social bots in high scale, high velocity, multi-language messaging. Final phase should be capable of flowing tweets from the Twitter API, the Gnip “firehose", etc. and be incorporable into systems of analytic workflows for a variety of military operational domains such as Humanitarian Assistance, Disaster Relief, influence operations, public affairs, and civil affairs.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The detection of social bots is a growing area of concern in business communities, government and non-government organizations.

REFERENCES:
1. arXIV. “The emerging threat from Twitter’s social capitalists.” MIT Technology Review (2 July 2014). www.technologyreview.com/view/528746/the-emerging-threat-from-twitters-social-capitalists/?utm_campaign=socialsync&utm_medium=social-post&utm_source=facebook

2. Bilton, Nick. “Friends, and Influence, for Sale Online.” New York Times (Bits). (20 April 2014). bits.blogs.nytimes.com/2014/04/20/friends-and-influence-for-sale-online/?_php=true&_type=blogs&_r=0

KEYWORDS: Information technology; threat detection; information operations; data mining; computational social science; social networks

N15A-T021 TITLE: Time-resolved Measurements of Temperature and Product Mass Fractions within Detonation-based Combustion Devices at Elevated Pressures and Temperatures

TECHNOLOGY AREAS: Air Platform, Sensors, Weapons

OBJECTIVE: Develop spectroscopic tools for the time-resolved measurement of combustion product mass fractions and temperatures within detonation channels, along the combustor axis, and across the nozzle exit plane of Rotating Detonation Engine (RDE) systems to characterize flow field features, support combustion efficiency calculations, and determine the combustor exit enthalpy conditions.

DESCRIPTION: Temporally-resolved measurements of the mass fractions and temperature of major combustion species in detonation-based combustion devices are necessary to complement and ensure accurate modeling of flow physics and chemistry. The predicted thermodynamic advantages of rotating detonation engines provide motivation for the continued development of diagnostic tools to experimentally validate such predictions and also provide insight into performance deficits that may occur during system development. The operation of pressure-gain combustion systems, such as rotating detonation engines, generates specific challenges due to the high pressure oscillations and stratified flow fields associated with various architectures. To investigate the characteristics and structure of the reacting flow fields through mass fraction and temperature measurements, 0.1 to 1 Megahertz (MHz) resolution rates are required. In situ measurements of mole or mass fractions of major combustion species (water (H2O), carbon monoxide (CO), carbon dioxide (CO2)) will allow temporal characterization of the widely varying flow field behavior under highly transient conditions. Such measurements must be made at regions along a combustor axis with sufficient temporal resolution (< 10 microseconds (μs)) to achieve discrete information of the flow condition; furthermore, such measurements should not require flow seeding.

The ability to effectively and practically measure major combustion species can be based upon various spectroscopic techniques such as spontaneous Raman and absorption spectroscopy. However, more complicated and less portable techniques such as coherent anti-Stokes Raman scattering (CARS), Raman-excited laser-induced electronic fluorescence, and laser-induced fluorescence can be considered if a practical approach could be determined. Accessibility and vibration would likely limit the broad use of such systems due to the challenges associated with their practical integration.

The objective of this effort is to develop high-speed, temporally resolved spectroscopic tools based on the spectroscopy of major species inherent to hydrocarbon fuel combustion, but at significantly higher combustion pressures (10-50 atmospheres (atm)) and temperatures (approximately equal to 3000 Kelvin (K)) than past techniques. This is due to the widely varying conditions associated with detonation events, especially near the detonation event itself. The techniques developed should be able to be applied to experimental combustors and engines with transmission paths ranging from 0.5 centimeters (cm) up to 5 cm and run time durations of several seconds. Vibration, large pressure and temperature variations, broadband attention (soot), and bandwidth requirements will generate significant challenges.

PHASE I: Determine enabling spectroscopic features and demonstrate a viable, proof-of-concept, non-intrusive combustion diagnostic tool (instrumentation, database, analysis method(s)) to arrive at H2O, CO, and CO2 mass fractions and temperatures at frequencies above 100kHz within combustors possessing narrow combustion channels (approximately 1 cm) and pressures up to 50 atm.

PHASE II: Develop and demonstrate a prototype diagnostic system (hardware and software) for the characterization of combustion phenomena associated with Rotating Detonation Engines. The demonstration(s) shall occur at engine-relevant conditions and durations. Results shall be post-processed such that they can be readily utilized for control strategies or for stand-alone performance assessments. At the completion of Phase II, the prototype hardware and software shall be delivered to the Government Point of Contact.

PHASE III: Further develop the prototype hardware for applications in full-scale military engines as well as for laboratory-scale use. Further develop the software to enable relevant output parameters applicable to any control strategy and to conduct engine health monitoring. At the completion of Phase III, the fully functional prototype hardware developed in Phase III for laboratory-scale use and the associated software for both control strategies and engine health monitoring shall be delivered to the Government Point of Contact.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: These spectroscopic techniques will produce the experimental capability to measure combustion dynamics near the injector plate of a rotating detonation engine and also provide insight on the combustion efficiency for such engines. The measurement approach will also be applicable for determining the performance and combustion characteristics associated with gas-turbines, power plants, IC engines, and turbine engines.

REFERENCES:
1. V. Nagali, and R.K. Hanson, “Design of a diode-laser sensor to monitor water vapor in high-pressure combustion gases,” Applied Optics, Vol. 36, No 36, pp. 9518-9527, Dec. 1997.

2. X. Ouyang and P. L. Varghese, “Selection of spectral lines for combustion diagnostics,” Applied Optics, Vol. 29, No. 33 pp 4884-4890, 20 November 1990.

3. X. Ouyang and P. L. Varghese, “Line-of-sight absorption measurements of high temperature gases with thermal and concentration boundary layers,” Applied Optics, Vol. 28, No. 18, pp. 3979-3984, 15 September 1989.

4. J. A. Silver, “Frequency-modulation spectroscopy for trace species detection: theory and comparison among experimental methods,” Applied Optics, Vol. 31, pp. 707-717, 1992.

5. D. S. Bomse, A. C. Stanton, and J. A. Silver, “Frequency-modulation and wavelength modulation spectroscopies: Comparison of experimental methods using a lead-salt diode laser,” Applied Optics, Vol. 31, pp. 718-731, 1992.

6. X. Zhou, X. Liu, J. Jeffries, and R. K. Hanson, “Development of a sensor for temperature and water concentration in combustion gases using a single tunable diode laser,” Measurement Science Technology, Vol. 14, pp. 1459-1468, 2003.

7. J. M. Seitzman, R. Tamma, R. Vijayan, “Infrared absorption based sensor approaches for high Pressure combustion,” AIAA Paper 97-0318, Los Angeles, January 1997.

8. A. Farooq, J. Jeffries, and R. K. Hanson, “In situ combustion measurements of H2O and temperature near 2.5 μm using tunable diode laser absorption,” Measurement Science Technology, Vol. 19, 2008.

9. Sanders S T, Baldwin J A, Jenkins T P, Baer D S and Hanson R K 2000 Diode-laser sensor for monitoring multiple combustion parameters in pulse detonation engines Proc. Combust. Inst. 28 587–94.

KEYWORDS: Combustion, High-Bandwidth Measurements, Laser Spectroscopy, Detonation, Combustion Efficiency, Energy Efficiency

N15A-T022 TITLE: Cyber Resiliency for Critical Cyber Physical Systems

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop general methods and technology for achieving resiliency against cyber-attack for cyber physical systems, while maintaining strict real-time requirements of the critical systems.

DESCRIPTION: Critical real-time cyber physical systems (control systems) are widely deployed within the Navy's infrastructures and assets. The current trend toward interconnectedness exposes many of these previously isolated systems onto external cyber environments.

A critical real-time control system often employs redundancy for resiliency against (physical) failures, using fault tolerant techniques such as dual modular redundancy, byzantine fault tolerant systems or quad-redundancy-control-systems [1,2,3]. These fault tolerant systems were designed and proven to be effective toward physical and random failures, where the failure is expected to affect only one (or a small portion) of the controllers. Software related failures and cyber-attacks, however, affect all of the redundant controllers which share or may be exposed to the malicious or erroneous failure vectors. The existing fault tolerant systems are ineffective against these types of cyber vulnerabilities. New methods and technologies need to be developed for enhancing current fault tolerant systems to also be resilient against cyber-attack and other system failures.

Developing cyber resiliency techniques for real-time cyber physical systems addressed in this STTR requires consideration of real-time cyber physical systems' two important and system dependent aspects:
1. Critical real-time control systems, in general, require that outputs are generated periodically and calculated within allowed time (epoch).
2. Critical real-time control systems drive the behavior of mechanical/physical systems, which follow the law of physics and have inertia; hence, they can tolerate loss of a sequence of internal states and control signals (outputs) for a limited period of time.

The objective of this topic is to develop methods and techniques for achieving resiliency on critical real-time control systems against cyber-attacks and other system failures for each individual controller itself. A resilient cyber physical system will continue to operate faithfully with minimal and tolerable disruption due to cyber-attacks and failures. This STTR does not solicit techniques targeted toward communication or networking aspects of control systems.

PHASE I: Define and develop a concept for achieving resiliency against cyber-attack for cyber physical systems. Select a particular cyber-physical system, such as machinery control, vehicular control/automation, drone (excluding power grid related systems or biomedical implants/devices), analyze the system parameters and requirements, and develop cyber resiliency techniques suitable for the system.

PHASE II: Develop a fully functioning prototype of cyber resiliency techniques, and demonstrate its efficacy within the actual, analog or simulation environment for the selected cyber physical system of Phase I.

PHASE III: Upon successful completion of Phase II, the performer provides support in transitioning the technology for Navy use. The performer may be asked to develop a plan for integrating the product into the Navy's embedded control systems for various ship-board naval applications.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Resilient real-time control systems are widely used in the commercial sector. They play critical roles in aviation, the automotive industry, machineries, manufacturing pipelines, industrial complexes, power plants, etc. These previously isolated systems are currently exposed to cyber-environments. A successful product of this STTR will contribute to satisfying commercial demands for resilient cyber physical system.

REFERENCES:
1. National Instrument, (2008) “Redundant System Basic Concepts,” http://www.ni.com/white-paper/6874/en/pdf

2. Castro, M.; Liskov, B. (2002). "Practical Byzantine Fault Tolerance and Proactive Recovery". ACM Transactions on Computer Systems (Association for Computing Machinery) 20 (4): 398–461.

3. General Electric, “A Revolutionary Approach: Quad Redundancy Control”, http://www.automation.com/pdf_articles/ge/QuadPac_WP_gft761.pdf

KEYWORDS: Cyber physical systems, Cyber security, Resiliency, Fault tolerant, Control Systems, Critical control system

N15A-T023 TITLE: Advanced Solid State Switch (Diode) Materials for High Rep Rate Pulse Power Systems and High Power Radio Frequency (HPRF) Applications

TECHNOLOGY AREAS: Materials/Processes, Electronics, Weapons

ACQUISITION PROGRAM: ONR 352: High Power Radio Frequency Research and Electromagnetic Railgun INP

OBJECTIVE: Develop, design, and fabricate new solid state switch (diode) materials and demonstrate them in standard form factor mountings. These switches are envisioned for use in HPRF applications on tri-service platforms. The proposers should concentrate on fast rise time, fast recombination time switching materials and switches which can be used in high repetition rate (100’s of kilohertz (kHz) to 1000’s of kHz) applications. Also, the demonstration designs should be able to support 150 Amperes (A) at a potential 1500 volts (V) at a repetition rate of 500 kHz, with improved thermal transfer over present commercial products. Use of R134a refrigerant or other cooling methods are permitted.

DESCRIPTION: Switches are a critical component for the pulsed power systems utilized to produce the high voltages/currents to drive the next generation HPRF production technology or to directly synthesize the HPRF from charged transmission lines. HPRF systems use a wide range of opening and closing switch technologies from traditional spark gap, gas insulated switches to solid state photoconductive switches. The shortfall of many of these switches and switch/media is that they do not support high repetition rate applications, being physics-limited to repetition rate-limited to kHz or 10’s of kHz pulse repetition frequency rates (PRF) when used to power a variety of RF emitters such as a non-linear transmission line or to directly synthesize HPRF when embedded in a transmission line.

The three physics phenomena that drive the switch/media shortfall in repetition rate are the electron/hole recombination time (recovery rate), the resistive losses in the switch, and the thermal transport capabilities/rates of the switch to the surrounding environment for continuous wave (CW) operation. For a demonstration application of the material developed, what is envisioned is a switch that would have a recovery time of less than 0.5 microseconds that could support a variety of HPRF systems and applications and should have picoseconds or less of jitter, when kept at a constant temperature.

A driving factor in the transition of the switches and material is a focus on the ability to manufacture both the material and switches in sufficient quantity for operational use. As the new HPRF systems will push the envelope of increased energy, PRF, and power on-target, the more robust the driving switch technology must become while remaining in a standardized commercial form. The Department of Defense is interested in further developing switch technology capabilities through the study of innovative and novel materials that will not only advance the current state-of-the-art, but also be safer and cheaper to utilize within HPRF systems. The switching mediums of interest include, but are not limited to, solid state materials that are both conventionally or optically triggered (i.e., photoconductive switches utilizing Silicon (Si), Gallium Arsenide (GaAs), Silicon Carbide (4H-SiC), Gallium Nitride (GaN), etc.). The challenge for switch technology development is improved performance in the PRF with jitters of 1 picosecond (ps) or less, for pulse lengths of < 10 nanoseconds (ns), and switch charge times between 10 ns to 100 ns. In addition, repetition rates in the 500 kHz to 1000 kHz regime are required. Threshold standoff voltage should be in excess of 1,500 V with an on current of 150A. It is anticipated that the materials and switches developed under this topic will be, or become, export controlled and ITAR restricted beyond Phase II development. The offeror should anticipate the use of a DD254 in the contract as well as security classification guidance at that point.

PHASE I: In this phase the feasibility of developing semiconductor materials to meet the threshold requirements will be determined along with the development of test material samples required to support further development. One of the candidate designs will be chosen and a more detailed design will be developed. Electromagnetic and circuit modeling and simulation of the switch design should be conducted, and results leading to the final design(s) should be documented and provided in the final report along with a data package on all proposed critical components in the baseline system design. Phase I demonstrations are highly encouraged within available scope under time and funding constraints.

Phase I Design Parameters:
• 1.5 kV switch voltage
• 900 ns or recovery time
• 150 A On Current
• 5 ns pulse lengths
• 10 picoseconds jitter
• 100 ns charge times
• 5 ns rise times
• 1 hour (hr) run time
• 100,000 Hz pulse repetition frequency

The awardees are expected to start the facilities clearance process, if one does not exist, during the Phase I award.

PHASE II: Based upon the Phase I results, design and construct new switching media and test using a brassboard switch and the chosen novel switching medium. The use of actual hardware and empirical data collection is expected for the performance analysis of the switch and switching medium and should be provided in the final report along with a data package on all critical components in the brassboard system. At the completion of Phase II, the prototype switch should be capable of demonstrating the following performance characteristics:

Phase II Design Parameters:
• 1.5 kV switch voltage or greater
• 500 ns or less recovery time
• 150 A On Current
• 10 ns pulse lengths
• 1 picoseconds jitter
• 100 ns charge times
• 1 ns rise times
• 500 kHz pulse repetition frequency
• 1 hr run time
• 500,000 Hz pulse repetition frequency
• packaged in a standard industrial form factor

The Phase II switch prototype must demonstrate a clear path towards addressing the scalability and manufacturability challenges along with packaging the system into a relatively useful volume. At this point, the prototype should be able to demonstrate switch capabilities with minimal secondary system support, even if for a short test cycle. Furthermore, a plan should be developed clearly stating the methodology for future secondary system reduction and scalability for a fully developed switch. All data collected in the analysis of the switch and switching medium of the prototype system will be included in the final report along with a data package on all critical system components. A DD-254 will be included with any Phase II award.

PHASE III: Phase III will consist of an operational demonstration of a fully capable, compact switch meeting the specified switch requirements (detailed below). The final switch will represent a complete solution and should be ruggedized for, at a minimum, testing in a dry, outdoor environment and integrated into an government system of the funding agencies choosing or new system if the government so desires.

The desired potential Phase III design parameters will include previously stated parameters but may require additional advancement to support 2 kV switch voltage or greater with a 8 hour system run time.

All data collected in the analysis of the switch and switching medium of the final system will be included in the final report along with a user's manual and a data package on all critical system components. The final component report shall be developed with performance specifications satisfying the targeted acquisition program requirements coordinated with technical point of contact. A preliminary design package and plan outlining the use of the switch in commercial switching applications should also be submitted with the final report.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: HPRF sources, and consequently switches, are used in a wide variety of commercial applications including the electric power industry, semiconductor processing, x-ray machines, pulsed power, and medical applications. These applications should be identified as a part of the Phase I and II proposal and a transition plan developed to use the material and devices in the commercial industry.

REFERENCES:
1. Morton, D.; Banister, J.; Levine, J.; Naff, T.; Smith, I.; Sze, H.; Warren, T.; Giri, D. V.; Mora, C.; Pavlinko, J.; Schleher, J.; Baum, C.E., "A 2MV, <300ps risetime, 100Hz pulser for generation of microwaves," Power Modulator and High Voltage Conference (IPMHVC), 2010 IEEE International, pp. 361,364, 23-27 May 2010.

2. Lehr, J.M.; Abdalla, M.D.; Burger, J.W.; Elizondo, J.M.; Fockler, J.; Gruner, F.; Skipper, M.C.; Smith, I.D.; Prather, W.D., "Design and development of a 1 MV, compact, self break switch for high repetition rate operation," Pulsed Power Conference, 1999. Digest of Technical Papers. 12th IEEE International, vol. 2, pp. 1199, 1202 vol. 2, 27-30 June 1999.

3. Corley, J. P.; Hodge, K. C.; Drennan, S. A.; Guthrie, D. W.; Navarro, J. M.; Johnson, D.L.; Lehr, J.M.; Rosenthal, S. E.; Elizondo, J.M., "Development/tests of 6-MV triggered gas switches at SNL," Pulsed Power Conference, 2003. Digest of Technical Papers. PPC-2003. 14th IEEE International, vol. 2, pp. 875, 878 Vol. 2, 15-18 June 2003.

4. Gilman, Charles; Lam, S. K.; Naff, J.T.; Klatt, M.; Nielsen, K., "Design and performance of the FEMP-2000: a fast risetime, 2 MV EMP pulser," Pulsed Power Conference, 1999. Digest of Technical Papers. 12th IEEE International, vol. 2, pp. 1437,1440, vol. 2, 27-30 June 1999.

5. John Maenchen, Jane Lehr, Larry K. Warne, et. al, "Fundamental Science Investigations to Develop a 6-MV Laser Triggered Gas Switch for ZR: First Annual Report" Sandia National Laboratories, March 2007, http://www.sandia.gov/pulsedpower/prog_cap/pub_papers/070217.pdf

6. Rohwein, G.J., "A Three Megavolt Transformer for PFL Pulse Charging," IEEE Transactions on Nuclear Science, vol. 26, no. 3, pp. 4211, 4213, June 1979.

7. Bailey, V.; Carboni, V.; Eichenberger, C.; Naff, T.; Smith, I.; Warren, T.; Whitney, B.; Giri, D.; Belt, D.; Brown, D.; Mazuc, A.; Seale, T., "A 6-MV Pulser to Drive Horizontally Polarized EMP Simulators," IEEE Transactions on Plasma Science, vol. 38, no. 10, pp.2554, 2558, Oct. 2010.

8. Belt, D.; Mazuc, A.; Sebacher, K.; Bailey, V.; Carboni, V.; Eichenberger, C.; Naff, T.; Smith, I.; Warren, T.; Whitney, B., "Operational performance of the Horizontal Fast Rise EMP pulser at the Patuxent River EMP test facility," Pulsed Power Conference (PPC), 2011 IEEE, pp. 551, 554, 19-23 June 2011.

9. Carboni, V.; Lackner, H.; Giri, D.; Lehr, J., "The breakdown fields and rise times of select gases under the conditions of fast charging (20 ns and less) and high pressures (20-100 atmospheres)," Pulsed Power Plasma Science, 2001. PPPS-2001. Digest of Technical Papers, vol. 1, pp. 482, 486 vol. 1, 17-22 June 2001.

10. James, C.; Hettler, C.; Dickens, J., "Design and Evaluation of a Compact Silicon Carbide Photoconductive Semiconductor Switch," IEEE Transactions on Electron Devices, Vol. 58, Issue 2, 2011.

11. Pocha, M.D.; Druce, R.L., "35-kV GaAs subnanosecond photoconductive switches," Electron Devices, IEEE Transactions on Electron Devices, Vol. 37 , Issue: 12 , Part: 2, 1990.

12. Karabegovic, A.; OConnell, Robert M.; Nunnally, W.C. "Photoconductive switch design for microwave applications," IEEE Transactions on Dielectrics and Electrical Insulation, Volume: 16, Issue: 4, 2009.

13. Zutavern, F.J.; Glover, S.F.; Mar, A.; Cich, M.J.; Loubriel, G.M.; Swalby, M.E.; Collins, R.T.; Greives, K.H.; Keator, N.D., "High current, multi-filament photoconductive semiconductor switching," IEEE Pulsed Power Conference (PPC), 2011.

KEYWORDS: High power radio frequency; high power microwave; dielectrics; closing switches; opening switches; spark gap; semiconductor solid state switches; photoconductive switches