

DEPARTMENT OF THE NAVY (DON)
21.1 Small Business Innovation Research (SBIR)
Proposal Submission Instructions

IMPORTANT

- **The following instructions apply to SBIR topics only:**
 - **N211-001 through N211-100**
- **The information provided in the DON Proposal Submission Instruction document takes precedence over the DoD Instructions posted for this Broad Agency Announcement (BAA).**
- **DON Phase I Technical Volume (Volume 2) page limit is not to exceed 10 pages.**
- **Proposers that are more than 50% owned by multiple venture capital operating companies (VCO), hedge funds (HF), private equity firms (PEF) or any combination of these are eligible to submit proposals in response to DON topics advertised in this BAA. Information on Majority Ownership in Part and certification requirements at time of submission for these proposers are detailed in the section titled ADDITIONAL NOTES.**
- A Phase I proposal template specific to DON topics will be available to assist small businesses to generate a Phase I Technical Volume (Volume 2). The template will be located on https://www.navysbir.com/links_forms.htm.
- The DON provides notice that Basic Ordering Agreements (BOAs) may be used for Phase I awards, and BOAs or Other Transaction Agreements (OTAs) may be used for Phase II awards.
- The Supporting Documents Volume (Volume 5) is available for the SBIR 21.1 BAA cycle. The Supporting Documents Volume is provided for small businesses to submit additional documentation to support the Technical Volume (Volume 2) and the Cost Volume (Volume 3). Volume 5 is available for use when submitting Phase I and Phase II proposals. DON will not be using any of the information in Volume 5 during the evaluation.

INTRODUCTION

The Director of the DON SBIR/STTR Programs is Mr. Robert Smith. For program and administrative questions, contact the SYSCOM Program Manager listed in [Table 1](#); **do not** contact them for technical questions. For technical questions about a topic, contact the Topic Authors listed within each topic during the Pre-release period. During the Open period the DoD SBIR/STTR Topic Q&A platform (<https://www.dodsbirsttr.mil/submissions>) must be used for any technical inquiry. Review section 4.13 of the Department of Defense (DoD) SBIR/STTR Program Broad Agency Announcement (BAA) for further information related to Direct Contact with Topic Authors and the Topic Q&A platform. For general inquiries or problems with electronic submission, contact the DoD SBIR/STTR Help Desk at 1-703-214-1333 (Monday through Friday, 9:00 a.m. to 5:00 p.m. ET) or via email at dodsbirsupport@reisystems.com.

TABLE 1: DON SYSTEMS COMMAND (SYSCOM) SBIR PROGRAM MANAGERS

<u>Topic Numbers</u>	<u>Point of Contact</u>	<u>SYSCOM</u>	<u>Email</u>
N211-001 to N211-002	Mr. Jeffrey Kent	Marine Corps Systems Command (MCSC)	jeffrey.a.kent@usmc.mil
N211-003 to N211-028	Ms. Donna Attick	Naval Air Systems Command (NAVAIR)	navair.sbir@navy.mil
N211-029 to N211-078	Mr. Dean Putnam	Naval Sea Systems Command (NAVSEA)	dean.r.putnam@navy.mil
N211-079 to N211-080	Mr. Shadi Azoum	Naval Information Warfare Systems Command (NAVWAR)	shadi.azoum@navy.mil
N211-081 to N211-090	Ms. Lore-Anne Ponirakis	Office of Naval Research (ONR)	loeranne.ponirakis@navy.mil
N211-091 to N211-100	Mr. Michael Pyryt	Strategic Systems Programs (SSP)	michael.pyryt@ssp.navy.mil

The DON SBIR/STTR Programs are mission-oriented programs that integrate the needs and requirements of the DON’s Fleet through research and development (R&D) topics that have dual-use potential, but primarily address the needs of the DON. More information on the programs can be found on the DON SBIR/STTR website 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 SBIR/STTR Program BAA at <https://www.dodsbirsttr.mil/submissions> for requirements and proposal submission guidelines. Please keep in mind that Phase I must address the feasibility of a solution to the topic. It is highly recommended that proposers follow the Phase I Proposal Template that is specific to DON topics as a guide for structuring proposals. The template will be located on https://navysbir.com/links_forms.htm. Inclusion of cost estimates for travel to the sponsoring SYSCOM’s facility for one day of meetings is recommended for all proposals.

Proposals that are not successfully certified in the Defense SBIR/STTR Innovation Portal (DSIP) prior to BAA Close will NOT be considered submitted. Please refer to section 5.1 of the DoD SBIR/STTR Program BAA for further information.

PHASE I PROPOSAL SUBMISSION REQUIREMENTS

The following MUST BE MET or the proposal will be deemed noncompliant and shall be REJECTED.

- **Proposal Cover Sheet (Volume 1).** As specified in DoD SBIR/STTR Program BAA section 5.4(a).

- **Technical Proposal (Volume 2).** Technical Proposal (Volume 2) must meet the following requirements:
 - Content is responsive to evaluation criteria as specified in DoD SBIR/STTR Program BAA section 6.0
 - Not to exceed **10** pages, regardless of page content
 - Single column format, single-spaced typed lines
 - Standard 8 ½” x 11” paper
 - Page margins one-inch on all sides. A header and footer may be included in the one-inch margin.
 - No font size smaller than 10-point*
 - Include, within the **10-page limit of Volume 2**, an Option that furthers the effort in preparation for Phase II and will bridge the funding gap between the end of Phase I and the start of Phase II. Tasks for both the Phase I Base and the Phase I Option must be clearly identified.

*For headers, footers, listed references, and imbedded tables, figures, images, or graphics that include text, a font size smaller than 10-point is allowable; however, proposers are cautioned that the text may be unreadable by evaluators.

Volume 2 is the technical proposal. Additional documents may be submitted to support Volume 2 in accordance with the instructions for Supporting Documents Volume (Volume 5) as detailed below.

Disclosure of Information (DFARS 252.204-7000)

In order to eliminate the requirements for prior approval of public disclosure of information (in accordance with DFARS 252.204-7000) under this or any subsequent award, the proposer shall identify and describe all fundamental research to be performed under its proposal, including subcontracted work, with sufficient specificity to demonstrate that the work qualifies as fundamental research. Fundamental research means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons. Simply identifying fundamental research in the proposal does NOT constitute acceptance of the exclusion. All exclusions will be reviewed and noted in the award. NOTE: Fundamental research included in the technical proposal that the proposer is requesting be eliminated from the requirements for prior approval of public disclosure of information, must be uploaded in a separate document (under “Other”) in the Supporting Documents Volume (Volume 5).

Phase I Options are typically exercised upon selection for Phase II. Option tasks should be those tasks that would enable rapid transition from the Phase I feasibility effort into the Phase II prototype effort.

- **Cost Volume (Volume 3).** The Phase I Base amount must not exceed \$140,000 and the Phase I Option amount must not exceed \$100,000. Costs for the Base and Option must be separated and clearly identified on the Proposal Cover Sheet (Volume 1) and in Volume 3.
- **Period of Performance.** The Phase I Base Period of Performance must be exactly six (6) months and the Phase I Option Period of Performance must be exactly six (6) months.

- **Company Commercialization Report (Volume 4).** DoD requires Volume 4 for submission to the 21.1 Phase I BAA. Please refer to instructions provided in section 5.4.e of the DoD SBIR/STTR Program BAA.
- **Supporting Documents (Volume 5).** Volume 5 is available for use when submitting Phase I and Phase II proposals.

The DoD must comply with Section 889(a)(1)(B) of the FY2019 National Defense Authorization Act (NDAA) and is working to reduce or eliminate contracts, or extending or renewing a contract with an entity that uses any equipment, system, or service that uses covered telecommunications equipment or services as a substantial or essential component of any system, or as critical technology as part of any system. **As such, all proposals must include as a part of their submission a written certification in response to the NDAA clauses (Federal Acquisition Regulation clauses 52.204-24, 52-204-25 and 52-204-26).** The written certification can be found in Attachment 1 of the DoD SBIR/STTR Program BAA. This certification must be signed by the authorized company representative and is to be uploaded as a separate PDF file in Volume 5. Failure to submit the required certification as a part of the proposal submission process will be cause for rejection of the proposal submission without evaluation. Please refer to instructions provided in section 5.4.g of the DoD SBIR/STTR Program BAA.

A proposal that has an answer of “Yes” to any question regarding foreign investment disclosure in the Firm Certifications section of Volume 1 (Proposal Cover Sheet) must then include as part of their submission a Foreign Disclosure Addendum. The Foreign Disclosure Addendum can be found in Attachment 2 of the DoD SBIR/STTR Program BAA. The addendum, if required, must be completed by the authorized company representative and uploaded as a separate PDF file in Volume 5. Please refer to instructions provided in section 5.4.h of the DoD SBIR/STTR Program BAA.

Volume 5 is available for small businesses to submit additional documentation to support the Technical Proposal (Volume 2) and the Cost Volume (Volume 3). A template is available on https://navysbir.com/links_forms.htm. DON will not be using any of the information in Volume 5 during the evaluation.

- Letters of Support relevant to this project
- Additional Cost Information
- SBIR/STTR Funding Agreement Certification
- Data Rights
- Allocation of Rights between Prime and Subcontractor
- Disclosure of Information (DFARS 252.204-7000)
- Prior, Current, or Pending Support of Similar Proposals or Awards
- Foreign Citizens
- Majority-Owned VCOC, HF, and PEF Certification, if applicable

NOTE: The inclusion of documents or information other than that listed above (e.g., resumes, test data, technical reports, publications) may result in the proposal being deemed “Non-compliant” and REJECTED.

A font size smaller than 10-point is allowable for documents in Volume 5; however, proposers are cautioned that the text may be unreadable.

- **Fraud, Waste and Abuse Training Certification (Volume 6).** DoD requires Volume 6 for submission to the 21.1 Phase I BAA. Please refer to instructions provided in section 5.4.i of the DoD SBIR/STTR Program BAA.

DON SBIR PHASE I PROPOSAL SUBMISSION CHECKLIST

- **Subcontractor, Material, and Travel Cost Detail.** In the Cost Volume (Volume 3), proposers must provide sufficient detail for subcontractor, material and travel costs. Enter this information in the “Explanatory Material” field in the online DoD Volume 3. Subcontractor costs must be detailed to the same level as the prime contractor. Material costs must include a listing of items and cost per item. Travel costs must include the purpose of the trip, number of trips, location, length of trip, and number of personnel. When a proposal is selected for award, be prepared to submit further documentation to the SYSCOM Contracting Officer to substantiate costs (e.g., an explanation of cost estimates for equipment, materials, and consultants or subcontractors).
- **Performance Benchmarks.** Proposers must meet the two benchmark requirements for progress toward Commercialization as determined by the Small Business Administration (SBA) on June 1 each year. Please note that the DON applies performance benchmarks at time of proposal submission, not at time of contract award.
- **Discretionary Technical and Business Assistance (TAB A).** If TAB A is proposed, the information required to support TAB A (as specified in the TAB A section below) must be added in the “Explanatory Material” field of the online DoD Volume 3. If the supporting information exceeds the character limits of the Explanatory Material field of Volume 3, this information must be included in Volume 5 as “Additional Cost Information” as noted above. Failure to add the required information in the online DoD Volume 3 and, if necessary, Volume 5 will result in the denial of TAB A. TAB A may be proposed in the Base and/or Option periods, but the total value may not exceed \$6,500 in Phase I.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TAB A)

The SBIR and STTR Policy Directive section 9(b) allows the DON to provide TAB A (formerly referred to as DTA) to its awardees. The purpose of TAB A is to assist awardees in making better technical decisions on SBIR/STTR projects; solving technical problems that arise during SBIR/STTR projects; minimizing technical risks associated with SBIR/STTR projects; and commercializing the SBIR/STTR product or process, including intellectual property protections. Firms may request, in their Phase I Cost Volume (Volume 3) and Phase II Cost Volume, to contract these services themselves through one or more TAB A providers in an amount not to exceed the values specified below. The Phase I TAB A amount is up to \$6,500 and is in addition to the award amount. The Phase II TAB A amount is up to \$25,000 per award. The TAB A amount, of up to \$25,000, is to be included as part of the award amount and is limited by the established award values for Phase II by the SYSCOM (i.e. within the \$1,700,000 or lower limit specified by the SYSCOM). As with Phase I, the amount proposed for TAB A cannot include any profit/fee application by the SBIR/STTR awardee and must be inclusive of all applicable indirect costs. A Phase II project may receive up to an additional \$25,000 for TAB A as part of one additional (sequential) Phase II award under the project for a total TAB A award of up to \$50,000 per project.

Approval of direct funding for TAB A will be evaluated by the DON SBIR/STTR Program Office. A detailed request for TAB A must include:

- TAB A provider(s) (firm name)
- TAB A provider(s) point of contact, email address, and phone number
- An explanation of why the TAB A provider(s) is uniquely qualified to provide the service
- Tasks the TAB A provider(s) will perform

- Total TABA provider(s) cost, number of hours, and labor rates (average/blended rate is acceptable)

TABA must NOT:

- Be subject to any profit or fee by the SBIR applicant
- Propose a TABA provider that is the SBIR applicant
- Propose a TABA provider that is an affiliate of the SBIR applicant
- Propose a TABA provider that is an investor of the SBIR applicant
- Propose a TABA provider that is a subcontractor or consultant of the requesting firm otherwise required as part of the paid portion of the research effort (e.g., research partner, consultant, tester, or administrative service provider)

TABA must be included in the Cost Volume (Volume 3) as follows:

- Phase I: The value of the TABA request must be included on the TABA line in the online DoD Volume 3 and, if necessary, Volume 5 as described above. The detailed request for TABA (as specified above) must be included in the “Explanatory Material” field of the online DoD Volume 3 and be specifically identified as “Discretionary Technical and Business Assistance”.
- Phase II: The value of the TABA request must be included on the TABA line in the DON Phase II Cost Volume (provided by the DON SYSCOM). The detailed request for TABA (as specified above) must be included as a note in the Phase II Cost Volume and be specifically identified as “Discretionary Technical and Business Assistance”.

TABA may be proposed in the Base and/or Option periods. Proposed values for TABA must NOT exceed:

- Phase I: A total of \$6,500
- Phase II: A total of \$25,000 per award, not to exceed \$50,000 per Phase II project

NOTE: Section 9(b)(5) of the SBIR and STTR Policy Directive requires that a firm receiving technical or business assistance from a vendor during a fiscal year submit a report with a description of the technical or business assistance received and the benefits and results of the technical or business assistance provided. More information on the reporting requirements of awardees that receive TABA funding through the DON can be found on https://www.navysbir.com/links_forms.htm. Awardees that receive TABA funding through the DON will upload the report to <https://www.navysbirprogram.com/navydeliverables/>.

If a proposer requests and is awarded TABA in a Phase II contract, the proposer will be eliminated from participating in the DON SBIR/STTR Transition Program (STP), the DON Forum for SBIR/STTR Transition (FST), and any other assistance the DON provides directly to awardees.

All Phase II awardees not receiving funds for TABA in their awards must attend a one-day DON STP meeting during the first or second year of the Phase II contract. This meeting is typically held in the spring/summer in the Washington, D.C. area. STP information can be obtained at: <https://navystp.com>. Phase II 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.

EVALUATION AND SELECTION

The DON will evaluate and select Phase I and Phase II proposals using the evaluation criteria in Sections 6.0 and 7.0 of the DoD SBIR/STTR Program BAA respectively, with technical merit being most important, followed by qualifications of key personnel and commercialization potential of equal importance. As noted in the sections of the aforementioned Announcement on proposal submission requirements, proposals exceeding the total costs established for the Base and/or any Options as specified by the sponsoring DON

SYSCOM will be rejected without evaluation or consideration for award. Due to limited funding, the DON reserves the right to limit the number of awards under any topic.

Approximately one week after the Phase I BAA closing, e-mail notifications that proposals have been received and processed for evaluation will be sent. Consequently, the e-mail address on the proposal Cover Sheet must be correct.

Requests for a debrief must be made within 15 calendar days of select/non-select notification via email as specified in the select/non-select notification. Please note debriefs are typically provided in writing via email to the Corporate Official identified in the firm proposal within 60 days of receipt of the request. Requests for oral debriefs may not be accommodated. If contact information for the Corporate Official has changed since proposal submission, a notice of the change on company letterhead signed by the Corporate Official must accompany the debrief request.

Protests of Phase I and II selections and awards must be directed to the cognizant Contracting Officer for the DON Topic Number, or filed with the Government Accountability Office (GAO). Contact information for Contracting Officers may be obtained from the DON SYSCOM Program Managers listed in Table 1. If the protest is to be filed with the GAO, please refer to instructions provided in section 4.11 of the DoD SBIR/STTR Program BAA.

Protests to this BAA and proposal submission must be directed to the DoD SBIR/STTR Program BAA Contracting Officer, or filed with the GAO. Contact information for the DoD SBIR/STTR Program BAA Contracting Officer can be found in section 4.11 of the DoD SBIR/STTR Program BAA.

CONTRACT DELIVERABLES

Contract deliverables for Phase I are typically a kick-off brief, progress reports, and a final report. Required contract deliverables must be uploaded to <https://www.navysbirprogram.com/navydeliverables/>.

AWARD AND FUNDING LIMITATIONS

Awards. The DON typically awards a Firm Fixed Price (FFP) contract or a small purchase agreement for Phase I. In addition to the negotiated contract award types listed in Section 4.12.b of the DoD SBIR/STTR Program BAA, for Phase II awards the DON may (under appropriate circumstances) propose the use of an Other Transaction Agreement (OTA) as specified in 10 U.S.C. 2371/10 U.S.C. 2371b and related implementing policies and regulations. The DON may choose to use a Basic Ordering Agreement (BOA) for Phase I and Phase II awards.

Funding Limitations. In accordance with the SBIR and STTR Policy Directive section 4(b)(5), there is a limit of one sequential Phase II award per firm per topic. Additionally, to adjust for inflation DON has raised Phase I and Phase II award amounts. The maximum Phase I proposal/award amount including all options (less TABA) is \$240,000. The Phase I Base amount must not exceed \$140,000 and the Phase I Option amount must not exceed \$100,000. The maximum Phase II proposal/award amount including all options (including TABA) is \$1,700,000 (unless non-SBIR/STTR funding is being added). Individual SYSCOMs may award amounts, including Base and all Options, of less than \$1,700,000 based on available funding. The structure of the Phase II proposal/award, including maximum amounts as well as breakdown between Base and Option amounts will be provided to all Phase I awardees either in their Phase I award or a minimum of 30 days prior to the due date for submission of their Initial Phase II proposal.

PAYMENTS

The DON makes three payments from the start of the Phase I Base period, and from the start of the Phase I Option period, if exercised. Payment amounts represent a set percentage of the Base or Option value as follows:

Days From Start of Base Award or Option	Payment Amount
15 Days	50% of Total Base or Option
90 Days	35% of Total Base or Option
180 Days	15% of Total Base or Option

TRANSFER BETWEEN SBIR AND STTR PROGRAMS

Section 4(b)(1)(i) of the SBIR and STTR Policy Directive provides that, at the agency's discretion, projects awarded a Phase I under a BAA for SBIR may transition in Phase II to STTR and vice versa. Please refer to instructions provided in section 7.2 of the DoD SBIR/STTR Program BAA.

ADDITIONAL NOTES

Majority Ownership in Part. Proposers which are more than 50% owned by multiple venture capital operating companies (VCOC), hedge funds (HF), private equity firms (PEF), or any combination of these as set forth in 13 C.F.R. § 121.702, are eligible to submit proposals in response to DON topics advertised within this BAA.

For proposers that are a member of this ownership class the following must be satisfied for proposals to be accepted and evaluated:

- a. Prior to submitting a proposal concerns must register with the SBA Company Registry Database.
- b. The proposer within its submission must submit the Majority-Owned VCOC, HF, and PEF Certification. The SBIR VC Certification must be included in the Supporting Documents Volume (Volume 5). A copy of the SBIR VC Certification can be found on https://navysbir.com/links_forms.htm.
- c. Should a proposer become a member of this ownership class after submitting its application and prior to any receipt of a funding agreement, the proposer must immediately notify the Contracting Officer, register in the appropriate SBA database, and submit the required certification which can be found on https://navysbir.com/links_forms.htm.

System for Award Management (SAM). It is strongly encouraged that proposers register in SAM, <https://beta.sam.gov>, by the Close date of this BAA, or verify their registrations are still active and will not expire within 60 days of BAA Close. Additionally, proposers should confirm that they are registered to receive contracts (not just grants) and the address in SAM matches the address on the proposal.

Human Subjects, Animal Testing, and Recombinant DNA. Due to the short timeframe associated with Phase I of the SBIR/STTR process, the DON 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 DON 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 DON'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 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.

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

International Traffic in Arms Regulation (ITAR). For topics indicating ITAR restrictions or the potential for classified work, limitations are generally placed on disclosure of information involving topics of a classified nature or those involving export control restrictions, which may curtail or preclude the involvement of universities and certain non-profit institutions beyond the basic research level. Small businesses must structure their proposals to clearly identify the work that will be performed that is of a basic research nature and how it can be segregated from work that falls under the classification and export control restrictions. As a result, information must also be provided on how efforts can be performed in later phases if the university/research institution is the source of critical knowledge, effort, or infrastructure (facilities and equipment).

Support Contract Personnel for Administrative Functions. Proposers are advised that support contract personnel will be used to carry out administrative functions and may have access to proposals, contract award documents, contract deliverables, and reports. All support contract personnel are bound by appropriate non-disclosure agreements.

PHASE II GUIDELINES

All Phase I awardees can 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 proposer's potential to progress to a workable prototype in Phase II and transition technology to 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 contract 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).

The DON typically awards a Cost Plus Fixed Fee contract for Phase II; but, may consider other types of agreement vehicles. Phase II awards can be structured in a way that allows for increased funding levels based on the project's transition potential. To accelerate the transition of SBIR/STTR-funded technologies to Phase III, especially those that lead to Programs of Record and fielded systems, the Commercialization Readiness Program was authorized and created as part of section 5122 of the National Defense Authorization Act of Fiscal Year 2012. The statute set-aside is 1% of the available SBIR/STTR funding to be used for administrative support to accelerate transition of SBIR/STTR-developed technologies and provide non-financial resources for the firms (e.g., the DON STP).

PHASE III GUIDELINES

A Phase III SBIR/STTR award is any work that derives from, extends, or completes effort(s) performed under prior SBIR/STTR funding agreements, but is funded by sources other than the SBIR/STTR programs. This covers any contract, grant, or agreement issued as a follow-on Phase III award or any contract, grant, or agreement award issued as a result of a competitive process where the awardee was an SBIR/STTR firm that developed the technology as a result of a Phase I or Phase II award. The DON will give Phase III status to any award that falls within the above-mentioned description, which includes assigning SBIR/STTR Data

Rights to any noncommercial technical data and/or noncommercial computer software delivered in Phase III that was developed under SBIR/STTR Phase I/II effort(s). Government prime contractors and/or their subcontractors must follow the same guidelines as above and ensure that companies operating on behalf of the DON protect the rights of the SBIR/STTR firm.

NAVY 21.1 SBIR Topics

- N211-001 Non-Lethal Payloads for Long-range Intermediate Force Capabilities on Small Tactical Vehicles and Unmanned Systems
- N211-002 Just-In Time Medical Logistics Resupply System for Forward Medical
- N211-003 Real-Time Detection, Location, and Isolation of High-Resistance, Wye Power System Ground Faults
- N211-004 Naval Aircrew Specific Body Armor Release
- N211-005 Packaged Mid-Infrared Non-Mechanical Beam Steerer
- N211-006 Improving Performance of Solid Rocket Fuel through Advancements in Materials Science
- N211-007 Hyperspectral Sensor Metamaterial Lens in Imaging Applications
- N211-008 Tool to Predict Transient Spatial-Temporal Boundary Conditions for Processing Autoclave-cured Composite Parts
- N211-009 Cyber Protection for Physical Avionics Data Inputs to Navy Platforms
- N211-010 Cloud Based Air Traffic Control Training System
- N211-011 Ping Strategies for an Intelligent Search using Multistatic Active Sonar
- N211-012 Micro-Electromechanical Gyroscope for Improved Inertial Navigation Systems Performance
- N211-013 Cooling Devices for Helmeted Maintainers, Flight Deck Crew, and Rotary-Wing Aircrew
- N211-014 Predictive Model Based Control System for High Speed Dynamic Airframe Testing
- N211-015 Long-Wave Infrared Transceivers for High Speed Free Space Optical Communications in Adverse Weather Conditions
- N211-016 Lightweight Thermal Protection System for Hypersonic Aerial Vehicles
- N211-017 Sonobuoy Improvements for Multistatic Active Sonar
- N211-018 Non-Traditional Airborne Anti-Submarine Warfare (ASW) System
- N211-019 Aging Prediction of Airworthiness of Aircraft Composite Components Accounting for Flight and Environmental Conditions
- N211-020 Digital Firing Device
- N211-021 High-Efficiency Midinfrared LEDs with High Brightness for High-Fidelity Infrared Scene Projection
- N211-022 High Performance Continuous Wave Quantum Cascade Lasers Immune to Output Facet Optical Damage
- N211-023 Collaborative Workspace for Next-Generation Navy Mission Planning System
- N211-024 Munitions Lifting Assembly Sunshade Cover

N211-025 Manned-Unmanned Air Vehicle Team Tactical Cloud Analysis

N211-026 Boron-Based Energetics

N211-027 Ultra-Lightweight Protection Shielding Material Against Electromagnetic Interference/Electromagnetic Pulse for Avionics

N211-028 Conformal Antennas Miniaturized through Magneto-Dielectric Materials

N211-029 Recovery and Handling of Group 3 through Group 5 Unmanned Aerial Vehicles Aboard Navy's Expeditionary Sea Base

N211-030 Kilowatt (kW) Class Continuous Wave (CW) and Pulse Laser Hardened Optical Systems for Submarines

N211-031 Compact RAMAN System for Marine Wave Boundary Characterization

N211-032 Extra Large Unmanned Undersea Vehicle (XLUUV) Launch and Recovery, On-Board Handling, and Servicing System

N211-033 Wireless Sensing to Improve Submarine Machinery Health Monitoring

N211-034 Submarine Atmospheric Contaminant Scrubbing Technology

N211-035 Compact Battery Power Uncooled 5 kW-Class Laser System

N211-036 Innovative Simultaneous Localization and Mapping Techniques for Unmanned Underwater Vehicles

N211-037 Electronic Warfare Operator Workload Organization and Sharing

N211-038 Next Generation Laminated Bus Bar Technologies

N211-039 24/7 Reachback Artificial Intelligence Support Environment for Anti-submarine Warfare (ASW)

N211-040 Submarine Deep Escape

N211-041 Compact Cryocooler for Maritime Operations

N211-042 Sensitivity and Resolution Improvements for Small-Aperture Marine RADAR

N211-043 Intelligent Corrosion Simulation and Design Tool

N211-044 Inflatable Deployable Sail Systems for Future Submarines

N211-045 Extended Life and Low Maintenance Aircraft Tie Down Fitting

N211-046 Undersea Warfare Decision Support System Coalition Data Parser & Advanced Display

N211-047 Unmanned Underwater-Vehicle (UUV) Mission Sensitive Energy Usage Optimization Using Automated Intelligent Services

N211-048 Unified Operational Picture for Anti-Submarine Warfare

N211-049 High Power MegaWatt (MW) Class Grating for High Energy Laser (HEL) System

N211-050 Electronic Warfare System Alert Monitoring, Prioritization, and Display

N211-051 Non-acoustic, High Fidelity, Short Range Underwater Tracking System

N211-052 Navigational Positioning Source Using Very Low Frequency Signals

N211-053 Nickel-Zinc Submarine Main Storage Battery

N211-054 High Strength Composite System for Ships

N211-055 High Dynamic Range and Low Noise Figure (NA) Integrated Microwave Photonic Transceiver for 6G mmWave Radio

N211-056 Propulsor Geometric Certification System

N211-057 Flight Deck Tie Downs

N211-058 Automated Unmanned Systems (UxS) Boundary Protection Capability

N211-059 High Temperature, Low Dielectric Constant Ceramic Fibers for Missile Applications

N211-060 Human-Machine Interface for Directed Energy Weapons

N211-061 Fast and Efficient Read-Out for Staring Focal Plane Arrays

N211-062 Nondestructive Detection of Flaws through Thick Polymers using Electromagnetic Imaging Technologies

N211-063 Compact, Efficient, High Power Direct-to-Green Laser Source

N211-064 Low Cost Deepwater Delivery Systems

N211-065 Adaptive Narrowband Trainer

N211-066 Coupled Control of Expeditionary Remote Operating Vehicles (ROV) and Manipulator Payloads

N211-067 Atomic Inertial Sensor as an Alternate Position Source

N211-068 S-Band Antenna System for Littoral Combat Ship Communications Relay

N211-069 Medium Voltage Direct Current (MVDC) Partial Discharge and Space Charge Test Apparatus for Cable and Insulated Bus Pipe (IBP)

N211-070 Lightweight Diver Handheld Underwater Hydraulic Friction Stud Welding System for 5000 Series Aluminum

N211-071 Nondestructive Evaluation (NDE) of Coated Multi-layered Fiber Reinforced Polymer (FRP) Components

N211-072 Automated Anchor Handling System

N211-073 Intelligent Assistant for Anti-Submarine Warfare

N211-074 Efficient Data Management to Improve Navy Maintenance and Ship Operational Readiness

N211-075 Active Nano Antenna Emulator for Electromagnetic Simulation

N211-076 Autonomous Draft Determination

N211-077 Non-towed Broadband Acoustic Source

N211-078 Operator Analytics and Training Integration through Artificial Intelligence and Machine Learning

N211-079 Enhanced Situational Awareness Through Smart Geospatial Comparative Analysis

N211-080 Wideband Interference Suppression for Dynamic-range OptiMization (WISDOM)

N211-081 Novel Flow Control Strategies for High-Speed Inlets and Isolators

N211-082 Accelerated Learning Model for Increased Strategic and Tactical Decision Making Using Multi-player Games

N211-083 Automated Formal Verification of Software Defined Network Implementations

N211-084 Low Cost, Single Use Precision Aiming Device for Explosive Ordnance Disposal Disrupters and Tools

N211-085 Developing Alloy Compositions Conducive to Additive Manufacturing

N211-086 N-Polar Gallium Nitride High Electron Mobility Transistor in Low-Cost Process Technology for mm-wave Transceiver Applications

N211-087 Solid State High Voltage Power Module Development and Packaging for High Power Microwave Drivers

N211-088 Live, Virtual, and Constructive Cyber Battle Damage Assessment for Training

N211-089 Airborne LIDAR Ocean Temperature Measurement

N211-090 Refrigerant Vapor Quality Sensor

N211-091 Real-time Simulation of Radio Frequency (RF) Signal Returns from Complex Targets and Backgrounds

N211-092 Onboard Flight Ablation Sensor

N211-093 Real Time Single-Shot AI Enhanced Coherent Wavefront Sensing for Intelligence, Surveillance, and Reconnaissance (ISR) and Directed Energy Applications

N211-094 Compact Phase Locked Laser System for Atom Interferometric Inertial Sensors

N211-095 Age Effect Evaluation: Test Methodology

N211-096 Producibile Radiation-hardened Interconnects Technology

N211-097 Radar Seeker Model for Hypersonic Weapon Full Life Cycle Support

N211-098 Unconventional Navigation Approaches Using Signals of Opportunity

N211-099 Photon-Counting Image Sensors Using Complementary Metal-oxide Semiconductor (CMOS) Foundry Processes

N211-100 GPS Alternative for Reentry

N211-001 TITLE: Non-Lethal Payloads for Long-range Intermediate Force Capabilities on Small Tactical Vehicles and Unmanned Systems

RT&L FOCUS AREA(S): Autonomy; Directed energy

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a suite of compact multi-weapon system payloads that deliver scalable Intermediate Force Capability (IFC) effects combined with other military effects for: applicability and effectiveness in multiple domains; synergistic value of integrating the various IFC effects with other multi-use military capabilities in a common architecture, such as Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR); secure communications; and automated fire control systems, all integrated aboard small manned and unmanned systems (UxS) platforms. Platforms include small tactical vehicles/vessels and unmanned ground vehicles (UGVs) for both urban and austere terrains, unmanned aerial vehicles (UAVs) for both counter-air and ground support operations, unmanned surface vehicles (USVs) for both the littorals and open water operations, and unmanned underwater vehicles (UUVs).

DESCRIPTION: This SBIR topic seeks to develop a suite of more compact and lightweight long range non-lethal counter-personnel and counter-materiel payloads for integration on small tactical vehicles/platforms and UxS. These IFC payloads will support a variety of stabilization operations, gray zone warfare, and regular and irregular warfare missions across the full Range of Military Operations (ROMO) [Refs 1,2]. These non-lethal (NL)/IFC payloads with enhanced system performance seek to mitigate codified joint non-lethal weapon capability-gaps. There is Service transition interest in these NL/IFC payloads in both the Maritime (U.S. Navy and U.S. Coast Guard) and Ground (U.S. Army and USMC) domains as each Service currently desires IFCs via small/lightweight low-cost systems that can project/provide long-range IFCs. These desired effects across the full breadth of the ROMO must be accomplished with integration of these small NL/IFC payloads on tactical manned and unmanned platforms with significant reduced overall system size, weight, power consumption, thermal cooling (-55 degrees C to 125 degrees C) and lower system costs (SWAP/C2) [Ref 5]. Existing IFCs have known range and overall system size and weight limitations, i.e., the current COTS solutions only mitigate a very small portion of the codified Joint Requirements Oversight Council (JROC) approved counter-personnel and counter-materiel capability-gap. This topic supports future long range compact and lightweight IFC to provide long range hail and warn, non-lethal counter-personnel tasks: such as deny access, move, suppress, and disable individuals and non-lethal counter-materiel tasks: such as stop/disable vehicles, vessels and aircraft.

These new innovative compact/lightweight IFC payloads include existing, both commercial off the shelf (COTS) and developmental, NL weapon technologies/stimuli such as: (1) dazzling lasers, (2) 12 gauge/40mm non-lethal munitions (blunt impact, flashbang, riot control agents, human electro-muscular incapacitation, malodorant) with associated munition launching/targeting and fire control systems; (3) long range acoustic hailing devices, and (4) directed energy (DE) weapons such as counter-electronics

(e.g., high power microwave weapons) and Active Denial Technologies (ADT). These new innovative payloads shall also include new/novel non-lethal payloads with innovative human effects and new non-lethal stimuli such as optogenics modulation of high magnetic fields and other new non-lethal stimuli that provide long range IFCs such as: (1) long range hail and warn capabilities; (2) area denial – deny access capabilities; (3) human target suppression; (4) ability to move individuals and/or groups of individuals from open and confined spaces; and (5) ability to non-lethally incapacitate/disable threat human/material targets.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on Phase II of this project as set forth by DCSA and MCSC in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Develop a wide variety of non-lethal stimuli for integration on a small tactical vehicle/platform and small UxSs, ensuring that each payload will have a minimal cost (of \$10's of thousands of dollars vice payloads that cost > \$1M) and weigh less than 50-100 lbs and with a compact form-fit of < 3 cu ft.

Demonstrate the feasibility/effectiveness of these novel Non-Lethal/IFC payloads with existing non-lethal weapon effectiveness models and against real counter-material targets such as against relevant threat vehicle and vessel engine targets. Collect weapon effectiveness data at range, e.g., Radio Frequency (RF) Target Susceptibility data corresponding to a Radio Frequency (RF) - High Power Microwave (HPM) payload's waveform against a broad relevant set of targets (e.g., threat vehicle and vessel engine) and human effects and weapon effectiveness data for non-lethal counter-personnel payloads. Demonstrate individual NL/IFC payload weapon effectiveness and performance data as well as this same type of data for a "combined effect" suite of NL/IFC Payloads. Demonstrate meeting JNLWD/JIFCO/Marine Corps needs and establish that the NL/IFC payloads weapon concept can be employed throughout the Joint Services. Establish weapon concept feasibility/effectiveness by rigorous NL/IFC individual and combined effects testing against both threat personnel and counter-materiel targets. Phase I will not require human subject or animal subject testing. Provide a Phase II development plan with performance goals and key technical milestones that addresses technical risk reduction and defines the development of a suite of compact/lightweight/low-cost Phase II non-lethal/IFC payloads integrated to small manned and unmanned systems.

PHASE II: Develop a suite of optimized (size/weight/cost) Non-Lethal/IFC payloads integrated to small manned systems and UxSs. Evaluate the prototype NL/IFC payloads via rigorous counter-personnel and counter-materiel target testing at both the contractor's facilities and at DoD laboratories such as the Naval Surface Warfare Center - Dahlgren Division (NSWC- Dahlgren) test ranges. The JNLWD-JIFCO maintains a set of counter-personnel human effects and weapon effectiveness models and a full set of counter-personnel and counter-material test targets at various DoD labs. Deliver the suite of NL/IFC payloads for manned and unmanned systems to Government lab facilities to be independently assessed and evaluated, with minimal cost to the performer, to determine the weapon's capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for a suite of non-lethal/IFC payloads. Demonstrate system performance through the evaluation of the NL/IFC payload's ability to meet known non-lethal counter-personnel and counter-materiel capability-gaps. Confirm and verify modeling and analytical methods developed in Phase I to include measuring the required full range of parameters including numerous deployment cycles. Use evaluation results to refine

the prototype into an initial design that will meet the JIFCO/JNLWD/Marine Corps non-lethal/IFC payload requirements. Prepare a Phase III development plan to transition the technology to Joint Service use.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the JIFCO/JNLWD/Marine Corps in transitioning the technology for Joint Service use. Develop this suite of next-generation NL/IFC payloads as integrated on GOTS manned and unmanned systems. Evaluate these weapons to determine their effectiveness in operationally relevant environments, e.g., Limited Military User Assessments (LMUAs) held by various Services. Support the JIFCO/JNLWD/Marine Corps for test and validation to certify and qualify the system for Joint Service use.

A suite of compact, lightweight, low-cost long range non-lethal intermediate force capability payloads have significant commercial applications beyond the DoD including other government agencies such as the Department of Justice (DoJ) and the Department of Homeland Security (DHS) to include Customs and Border Protection, which have actively been researching these type of non-lethal counter-personnel and counter-materiel effects. Local civilian law enforcement has these specific type of missions to support both counter-personnel and counter-materiel missions for law enforcement as well as to mitigate terrorist acts. Currently overall system size, weight, and cost have hindered the use of these systems by these agencies. This SBIR topic specifically addresses overall system size, weight, power consumption, thermal cooling, and overall system cost all while drastically improving NL/IFC weapon performance.

REFERENCES:

1. Leimbach, Wendell. "The Commandant's Guidance for the DoD Non-Lethal Weapons Program." Marine Corps Gazette, May 2020. <https://www.jnlwp.defense.gov/Press-Room/In-The-News/Article/2213225/the-commandants-guidance-for-the-dod-non-lethl-weapons-program/>
2. Berger, David H. "Executive Agent's Planning Guidance 2020 – Intermediate Force Capabilities – Bridging the Gap Between Presence and Lethality." U.S. Department of Defense Non-Lethal Weapons Program, March 2020. <https://mca-marines.org/wp-content/uploads/DoD-NLW-EA-Planning-Guidance-March-2020.pdf>
3. Klein, David. "Unmanned Systems & Robotics in the FY2019 Defense Budget." <https://www.auvsi.org/%E2%80%8Bunmanned-systems-and-robotics-fy2019-defense-budget>
4. "Demand for unmanned surface vehicles driven by non-lethal assignments." GlobalData Plc 2020, John Carpenter House, John Carpenter Street, London, EC4Y OAN, UK, 24 Feb 2020. <https://www.globaldata.com/demnd-for-unmanned-surface-vehicles-driven-by-non-lethal-assignments/>
5. "MIL-STD-810G, DEPARTMENT OF DEFENSE TEST METHOD STANDARD: ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS" October 31, 2008. http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810G_12306/

KEYWORDS: Intermediate Force Capabilities; Non-Lethal Payloads; Non-Lethal Effects; Counter-Personnel Weapons; Counter-Materiel Weapons; Non-Lethal Payloads for Unmanned Systems

N211-002 TITLE: Just-In Time Medical Logistics Resupply System for Forward Medical

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Biomedical

OBJECTIVE: Reduce the workload on medical personnel through the development of a system that can provide automated real-time supply ordering, tracking, and monitoring capabilities to integrate into existing USMC medical logistics systems (e.g., Defense Medical Logistics Standard Support, DMLSS) and their operational parameters, DoD enterprise digital medical logistics systems, and medical common operating picture (MedCOP) management systems in order to allow demand-based just in time push/pull logistical resupply of medical consumables and supporting products.

DESCRIPTION: The USMC has a need for as-needed, just-in-time custom medical resupply. Current Authorized Medical Allowance List (AMAL) logistical resupply is handled through the push or pull of large resupply or consumable blocks consisting of 1-5 pallets of environmentally ruggedized cases (e.g., AMAL 636, Battalion Aid Supplies). These resupply blocks are a “one size fits all” approach based upon the projected needs for a fixed number of patients per a fixed time period and do not take into account the actual consumption rates of specific medical products. This approach drastically increases the logistical footprint and cannot flexibly adjust to specific needs as driven by operational use.

Advances in wireless information technology are bringing the Navy Medical Corpsmen new ways to monitor and track patients in the theater (e.g., the USAF Air Force Research Laboratory’s (AFRL’s) Battlefield Assisted Trauma Distributed Observation Kit or BATDOK, and Marine Corps Warfighting Laboratory’s (MCWL’s) prototype concept, Medical Common Operating Picture (MedCOP). Advances in automated and expeditionary Unmanned Systems (UxS) could be applied as new methods of “small-payload on the spot” delivery of critical medical resupply items, such as blood products or medical consumables (e.g., drugs, bandages, IV lines) to Navy Corpsmen. These technologies, when combined with supply tracking technologies such as RFID, offer the potential for the real-time tracking of medical consumable use rates and for automated Push-Pull resupply requests for medical consumables. For example, the consumption of intravenous needle/tubing kits in response to battlefield casualties can be automated to keep track of the number of kits on hand at a field medical facility and automatically send a demand signal for additional kits once a critical threshold is reached. Furthermore, artificial intelligence (AI) and machine learning (ML) algorithms can hypothetically be developed that can predict future resupply needs based upon operational tempo and tracked casualty types. Such a predictive algorithm could automatically send demand signals in advance of casualty arrival at a field medical facility.

A Just-in-Time Medical Logistical Resupply System (JITMEDLOG) relieves the Navy Medical Corpsmen from the necessity to actively track consumable use rates by automatically tracking usage and automatically initiating critical resupply via unmanned vehicles (UxV) or other expeditionary means. It offers the ability for custom delivery of needed medical supplies while avoiding waste and oversupply. JITMEDLOG further allows for a smaller initial deployment footprint, reducing the upfront logistical burden and allowing for the deployment of more mobile and expeditionary medical teams, which will be critical under Distributed Maritime Operations (DMO).

The proposed system must address the following requirements, at a minimum:

- The USMC seeks the development of new algorithms and architecture integration to add Just-In-Time Medical Logistical tracking technology and predictive algorithms to the Project Phoenix architecture (e.g., BATDOK, MedCOP).
- The JITMEDLOG shall integrate with BATDOK and the prototype MedCOP architecture.

- The JITMEDLOG shall integrate with existing DoD medical logistics systems (e.g., DMLSS).
- The JITMEDLOG shall be compatible with UAS critical resupply systems. Any JITMEDLOG hardware supporting this architecture shall comply with MIL-STD-810x standards for use in all operational environments to which the USMC deploys.
- The JITMEDLOG shall be designed for use by any Navy Medical Corpsman, regardless of Navy Enlisted/Officer Code or specialty, and include new user training and operator and maintainer manuals.
- System transactions shall be timestamped.
- The system shall be accessible to all Expeditionary Medical and Tactical C2 nodes on the network.
- The system architecture shall provide location and inventory of Class VIII supplies.
- The system architecture shall provide the ability to send/receive forms.
- User interfaces shall provide the ability to copy and paste information within various user screens/forms.
- The system shall create a network sharable list of all consumables.
- The system shall create a network sharable list of blood supply.
- The system shall create a network sharable list of equipment.
- The system shall automatically pull information from designated sensors or databases relevant for the display.
- The system shall allow the user to enter information relevant to the display.
- The system shall minimize data sets when possible through packet size and compression to leverage narrow bandwidth.
- The system shall be capable of operation in an A2AD environment in mind.

PHASE I: Develop a concept for an architecture for a Just-in-Time Medical Logistical Resupply System (JITMEDLOG) that meets the requirements described above. Demonstrate the feasibility of the concepts in meeting Marine Corps needs. Establish that the concepts can be developed into a useful product (software and hardware) for the Marine Corps. Prove feasibility through material testing and analytical modeling, as appropriate. Provide a Phase II development plan with performance goals and key technical milestones, and addresses technical risk reduction.

PHASE II: Develop a scaled prototype. Evaluate the prototype to determine its capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for the Just-in-Time Medical Logistical Resupply system. Demonstrate system performance through prototype evaluation and modeling or analytical methods over the required range of parameters, including numerous deployment cycles. Use evaluation results to refine the prototype into a design that meets Marine Corps requirements. Prepare a Phase III development plan to transition the technology to Marine Corps use.

PHASE III DUAL USE APPLICATIONS: Support the Marine Corps in transitioning the technology for Marine Corps use. Develop the Just-in-Time Medical Logistical Resupply system for evaluation to determine its effectiveness in an operationally relevant environment. Develop commercial operator and maintainer manuals and user new equipment training programs to support the system's operations and maintenance in the field environment. Support the Marine Corps for test and validation to certify and qualify the system for Marine Corps use.

JITMEDLOG technology has potential for use with commercial and non-governmental organization in remote areas such as interior Africa, remote parts of Alaska or Canada, the Amazon basin, or other places lacking in infrastructure. Such technology can be used for disaster relief or pandemic response and can support remote hospitals and other medical facilities, vaccination efforts, or even non-medical applications such as critical equipment or food/water deliveries.

REFERENCES:

1. "MIL-STD810H. Department of Defense Test Method Standard. 31 Jan 2019." http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/

2. "Zipline." 7 Jul 2020. <https://flyzipline.com/>
3. Bedi, Shireen. "BATDOK improves, tailors to deployed medics." Military Health System, 7 Jul 2020. <https://health.mil/News/Articles/2019/06/07/BATDOK-improves-tailors-to-deployed-medics>
4. "Defense Medical Logistics Standard Support." Military Health System, 7 Jul 2020. <https://www.health.mil/Military-Health-Topics/Technology/Defense-Medical-Logistics/Defense-Medical-Logistics-Standard-Support>

KEYWORDS: Medical; Logistics; Database; Artificial Intelligence; Machine Learning; Radio Frequency Identification; RFID; Just In Time; JIT

N211-003 TITLE: Real-Time Detection, Location, and Isolation of High-Resistance, Wye Power System Ground Faults

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Electronics; Human Systems; Information Systems

OBJECTIVE: Develop a solution, consisting of hardware and software, to detect and locate ground faults in a high-resistance, wye grounded, pulsed power system in real time.

DESCRIPTION: An existing system will benefit from increased ability to detect and locate ground faults. Although, solutions will ultimately integrate with equipment already available in said system's current health monitoring infrastructure, it is understood that new software and (in all likelihood) additional hardware will be needed to achieve the objective.

Ground faults occur due to insulation breakdown. A high-resistance, wye grounded, electrical power system is tolerant of one ground fault on any phase, but not multiple ground faults in different locations on the same phase. Since the existing system does not indicate when a first line-to-ground fault occurs, cables are regularly inspected using an insulation resistance tester. Although this process enables manual detection of ground faults, determining location for corrective action is more difficult. A less arduous, real time solution will assure that all ground faults are being detected and reported within milliseconds of occurring, which will increase overall safety of the system. The goal is to detect and locate the first ground fault virtually immediately, and correct it as soon as possible, so that there is never an instance in which two ground faults occur in different locations on the same phase.

Insulation breakdown in a particular location may result in a single line-to-ground fault. This line-to-ground fault causes very low fault currents, on the order of .01% of load current, and must be detected, located, and isolated before another ground fault occurs on the same phase. Shipboard ground faults can be located anywhere in runs of several hundred feet of hard-to-reach cable. Fault currents are in the milliamp (mA) range in a system that nominally carries several kiloamps (kAs). Thus, solutions must reliably and accurately detect and locate ground faults that generate signals orders of magnitude smaller than operational currents, which may be alternating or direct (AC/DC) depending on cable section. Operating voltage levels are also in the kV range.

Insulation breakdown in a second location may result in undesired large current flow between the two fault locations, resulting in catastrophic damage to the power system, its equipment, and possibly other high-power equipment.

The solution must be capable of detecting ground faults of 10,000 Ohms or less. False negatives should not occur below the 10,000-Ohm threshold, and false positives should be minimized as searching for non-existent cable faults would prove burdensome and decrease confidence in the detection system. A false positive rate of 1% or below is considered appropriate at this time, but an official requirement has not yet been established. Measuring the exact resistance value (in Ohms) of the fault is not as vital as simply identifying that a ground fault is present, so accuracy, resolution, and sensitivity of the measurement are not defined at this time. Location should be determined with reasonable accuracy and resolution (e.g., ± 10 s of feet) to decrease mean time to repair (MTTR). Solutions that significantly narrow down location of faults are preferred, since they will decrease the time required to find and fix the damaged cable.

In summary, an innovative approach is needed to indicate the presence and location of an active ground fault in real time, so that it can be remedied before a second ground fault occurs. Additional capability may include prognostics that detect/predict the formation of ground faults before they occur.

PHASE I: Develop a concept for detecting and locating ground faults with minimal impact to existing power architecture. Validate the concept and demonstrate feasibility utilizing modeling and simulation and other software/hardware tools. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype to validate/verify the technological approach. Demonstrate that a line-to-ground fault on a single phase, or formation of said fault, can be detected and located by the prototype system. The goal is to detect, locate, and correct the first fault before a second occurs in a different location on the same phase; therefore, a safe method for insertion of faults at known locations may be required for testing.

Determine if the solution will be effective at the voltage and current levels required. Fault detection and location results will be verified against requirements to confirm that the technology can reliably sense faults and estimate their position(s). Include preliminary calculation of false positive and false negative rates using the prototype system. Accuracy, resolution, sensitivity and other metrics will be assessed as deemed necessary.

Consider human factors, including how to best illustrate the presence and location of faults on a display so that maintainers understand where to go to resolve the issue. The graphical user interface should be easy to read, interact with, and understand. Validate that faults are indicated in an acceptable manner that may be integrated into existing systems.

PHASE III DUAL USE APPLICATIONS: Integrate solution at NAWCAD Lakehurst test site using a representative model that meets actual power requirements. Conduct extensive testing that includes all viable fault modes and locations, i.e., test ground faults in pertinent cable sections as detailed by SMEs (Subject Matter Experts). After detecting faults, use a secondary method (e.g., insulation resistance tester) to determine actual fault location and calculate percent error/accuracy of location measurement. If a fault is not present near the location specified within a certain distance threshold, it must be recorded as a false positive. Additionally, regular insulation resistance testing must continue to determine if any ground faults are going undetected. If so, these must be recorded as false negatives. Integrated Product Team (IPT) will determine accuracy and resolution requirements necessary for transition.

This SBIR topic may benefit private sector companies working with high-power electricity in the energy, industrial and transportation sectors. This may include power generation, transmission and distribution, including both AC and DC (e.g., photovoltaic) applications, large manufacturing/industrial plant operations, and high-power railroad applications. Any commercial application that utilizes high power and experiences relatively low-fault currents, in comparison to operational currents, may benefit.

REFERENCES:

1. "MIL-STD-1399 (Section 300) Part 1, Department of Defense Interface Standard, Section 300, Part 1, Low Voltage Electric Power, Alternating Current (25-Sept-2018)." Department of Defense. http://everyspec.com/MIL-STD/MIL-STD-1300-1399/MIL-STD-1399-SECT-300_PART-1_55833/
2. "MIL-STD-461G, Department of Defense Interface Standard: Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment (11-Dec-2015)." Department of Defense. http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-461G_53571/
3. "MIL-STD-810H, Department of Defense Test Method standard: Environmental Engineering Considerations and Laboratory Tests." Department of Defense. http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/

4. "MIL-DTL-901E, Detail specification: Shock Tests, H. I. (High-impact) Shipboard Machinery, Equipment, and Systems, Requirements for (20-Jun-2017)." Department of Defense. http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-901E_55988/
5. "MIL-STD-167/1A, Department of Defense Test Method Standard: Mechanical Vibrations of Shipboard Equipment (Type I-environmental and Type II-internally excited) (02-Nov-2005)." Department of Defense. http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-167-1A_22418/
6. "User Interface Design Basics." Office of the Assistant Secretary for Public Affairs. (n.d.). U.S. Department of Health and Human Services (HHS). Retrieved July 21, 2020, from <https://www.usability.gov/what-and-why/user-interface-design.html>

KEYWORDS: Ground-fault; high-power; pulsed-power; detection; sensors; diagnostics

N211-004

TITLE: Naval Aircrew Specific Body Armor Release

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Optimally design and develop an innovative, affordable body armor release capability for Rotary Wing Naval Air Crew.

DESCRIPTION: Combat rotorcraft operators strongly desire the capability to jettison negatively buoyant hard plates from their body armor in water survival situations without jettisoning their entire survival vest, especially in the event flotation fails to inflate. Hard plates are worn inside the vest and under gear, and usually load from the bottom which is then secured with hook/loop tape. Typical quick-release designs are gravity-based and rely upon the survivor to find and pull a strap to open the bottom. These gravity-based designs have been found to require multiple pulls and re-gripping the pull strap at ever higher positions to open the bottom. The hard plate's downward drop is also resisted by the specific gravity of water, as well as frictional resistance from the tight, compressive fit of a heavy vest load. Pin-and-cable quick-releases in typical "maritime" or "marine" vests are an improvement over pull-strap with hook-and-loop designs, but often require complicated rigging and careful donning, which are not often compatible with rapid launch operations. Automatic quick-release mechanisms may work but can pose other hazards; an automatically released plate in a submerged aircraft will contribute to the debris field through which survivors must swim (crews can number up to 40 individuals). An automatic system can also rob the surfacing survivor of his ballistic protection in what may well be a combat environment. Additionally, it is important that the hard plate release design avoid imposing additional dressed weight and bulk to the already burdened operator. In terms of dry weight, Crew Chiefs dressed in the summer combat configuration carry 52-60 additional pounds; most of it is carried on the front torso. The gear and armor load adds 3-6 inches to the front profile. Possible sources of confusion in an emergency are the round-beaded handle for flotation actuation, and the lozenge-beaded handle that releases the fall-arrest tether. These two releases are located near one another on the upper right and left chest. Although not required, it is highly recommended to work in coordination with the original equipment manufacturer (OEM) to ensure proper design and to facilitate transition of the final technology.

Aircrew need a hard plate release that, with commanded action and when retrofitted to existing vests that incorporate the ineffective gravity-based quick release, enable the below metrics.

- a. releases a single hard plate with a single motion, only requiring one gloved left or right hand by a typical male or female, blind-folded operator;
- b. releases respective sizes of Small Arms Protective Insert (SAPI)-cut, "shooter's cut", and "swimmer's cut" hard plate forms;
- c. does not appreciably increase the weight and bulk burden of the armored vest system;
- d. operates in windy or calm air and in turbulent or calm water conditions;
- e. operates at a submerged depth of less than or equal to 30 feet;
- f. operates in cold water (32 degrees F) through the range of freshwater and seawater salinities;
- g. operates in chlorinated swimming pool water;
- h. operates reliably in cold and hot ambient air;
- i. separates the plate from the vest within 2 seconds of actuation;
- j. resists inadvertent actuation while: traversing ship ladders/hatches, operating within 120 knot rotor outwash, conducting pre-flight inspections and boarding aircraft, flying routine missions, flying combat missions, and egressing aircraft in routine or emergency situations;
- k. does not create hazards (injury, foreign object debris, snag/trip, static discharge) in any mission or survival operations to include survivable vertical crash loads (those less than or equal to 5Gs);

- l. does not interfere with vest or vest gear, inflatable flotation, seat harnesses, fall arrest tethers, helmets or head-mounted gear, communication cords and devices, clothing or other body-mounted gear;
- m. does not impede water survival or land survival procedures to include raft boarding and hoisting;
- n. does not contribute to wearer's burn injury hazard;
- o. does not give away wearer's position in covert day or night operations;
- p. is resistant to naval aviation environments (salt spray, humidity, drop impact, exposure to petroleum/oil/lubricant contaminants; exposure to sun);
- q. has an obvious visual indicator for correct rigging.

Note: NAVAIR will provide Phase I performers with the appropriate guidance required for human research protocols so that they have the information to use while preparing their Phase II Initial Proposal. Institutional Review Board (IRB) determination as well as processing, submission, and review of all paperwork required for human subject use can be a lengthy process. As such, no human research will be allowed until Phase II and work will not be authorized until approval has been obtained, typically as an option to be exercised during Phase II.

Note: Any textile components used to develop the resulting material must be entirely manufactured in the United States of constituents wholly grown and/or produced in the United States.

PHASE I: Develop a plate release and demonstrate feasibility for retrofit and operation in any military approved commercial vest that incorporates a typical gravity-based quick release design. Resulting concepts should include a background section with explanatory figures describing the basic principles of the proposed technology concept, and publications or other references that outline the application being considered. Provide a 3-tiered work breakdown structure with a Gantt chart of Phase I design activities, and include make/break criteria and events. Submit Technical Performance Measures (TPMs) that will be tracked throughout Phases I-III for Government review and approval and include at a minimum: dry weight, bulk/profile, time from actuation to plate separation (from vest structure) while submerged in swimming pool water, human-operated reliability, and maintainer mean time to rig, inspect, and certify mechanism "safe-for-flight". Provide experimental work that shows the technology concept will quickly release hard plates in air and in water by an operator with a single hand and a single action. The Phase I effort will include prototype plans to be developed under Phase II.

Note: Please refer to the statement included in the Description above regarding human research protocol for Phase II.

PHASE II: Develop and validate the plate release technology by incorporating it into a Government-identified vest system design. Provide a detailed, 3-tiered work breakdown structure with a Gantt chart of Phase III activities that include make/break criteria and events, perform required quality assurance testing utilizing approved quality assurance measures, and track performance against agreed upon TPMs throughout Phase II. During the Phase II Option, perform testing of the technology in the form of a system level demonstration while incorporated in multiple size small and size x-large armored vests in a swimming pool. Include, in this non-exclusive list of desired Phase II deliverables, raw data, photography and/or video recording, data recording sheets, documentation of test devices (manufacturer, model, serial, accuracy, calibration status, etc.), test reports, draft engineering drawings, an interface control document, and a performance specification.

Note: Please refer to the statement included in the Description above regarding human research protocol for Phase II.

PHASE III DUAL USE APPLICATIONS: Finalize the developed armor plate release technology and provide a technical data package to include a performance specification, interface control document, and

engineering drawings in accordance with military standards. Develop and assist with required qualification testing and training. Finalize all testing. Document the quality assurance test program in accordance with industry best practices. Transition the technology to the Fleet as a retrofit, and to new procurements as required.

This topic may benefit the private sector in recreational equipment for which quick divestment of structure-mounted or body-mounted gear carriers are desirable or required for safety. Examples may include boat deck go-bags, back-packs, tool vests for workers at height, and tool vests for oil rig workers.

REFERENCES:

1. Kovach, G. "Deadly Osprey crash spurred safety changes." The San Diego Tribune, June 30, 2015. <https://www.sandiegouniontribune.com/military/sdut-osprey-crash-at-sea-command-investigation-2015jun30-story.html>
2. Quinn, R. "Beach Marine one of four killed in Iraq copter crash." The Virginian Pilot, December 7, 2006. https://www.pilotonline.com/military/article_57e53572-0cf4-5301-a6d0-2901302a4bb5.html

KEYWORDS: body armor; quick-release; hard plate; vest; drowning; water ditching

N211-005

TITLE: Packaged Mid-Infrared Non-Mechanical Beam Steerer

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Battlespace Environments; Weapons

OBJECTIVE: Design and develop a packaged, high-throughput, non-mechanical beam steering device that is able to maintain stable operation with multiple-wavelength laser sources in the midwave infrared (MWIR) band with high beam quality, efficiency, and power on target.

DESCRIPTION: Non-mechanical beam steering (NMBS) has numerous advantages over conventional mechanical gimbals, including high point-to-point steering speeds, low size, weight, and power consumption, and low operating costs. To date, NMBS devices have primarily been developed and matured in the short-wave and near-infrared bands. Recent advances in refractive NMBS technology have resulted in MWIR-compatible liquid crystal-based refractive devices [Refs 1, 2], but they have primarily been demonstrated at the laboratory scale and require additional development for Department of Defense (DoD) applications. Of particular interest is development of robust packaging for refractive NMBS devices that combines the steering head, associated optical components, and thermal management in a compact package that is able to operate from room temperature to beyond 55 degrees C, using the latest MIL-STD 810 for thermal testing. Additional considerations include optical optimization of refractive NMBS devices to improve throughput performance and steering magnitude.

Driven by DoD application requirements, the Navy seeks development of technologies capable of continuously steering a beam across the field of regard (FOR) without blind spots. Steerers should satisfy specifications including, but not limited to:

- point-to-point steering speed: Threshold of 1 kHz (1 ms point-to-point transition time) across >75% of the FOR, Objective of 10 kHz (100 μ s point-to-point transition time) for >75% of the FOR;
- angular steering range: Threshold of 15° horizontally by 2° vertically, Objective of 30° horizontally by 5° vertically;
- throughput: Threshold of 30%, Objective of 50%; and
- power-on-target: Threshold of >1 W, Objective of >10 W;
- beam quality: Threshold of M2 <5, Objective of M2<1.5;
- aperture: Threshold of 2 mm, Objective of 1 cm;
- total packaged beam steerer volume (including associated coupling optics and thermal management): Threshold of <50 cm³, Objective of <10cm³; and
- electrical power consumption of the steerer head and associated thermal management while under active illumination: Threshold <10 W, Objective <1 W.

While it is desired that the full angular steering range be accessible without any wavelength-based steering effects, solutions that incorporate wavelength-tuning methods may be considered. The steerer must be capable of transitioning between any arbitrary points within the FOR and holding position at any arbitrary point; the primary operation mode necessary to achieve threshold and objective specifications should not be a continuous raster scan. The designed device must be able to accommodate coupling and steering of multiple laser lines, individually, but in a single device, between 2-5 μ m with high efficiency.

The design should reasonably expect to achieve a manufacturing readiness level (MRL) of 5 within 3 years and MRL 7 within 5 years of beginning work on this NMBS device.

PHASE I: Design, develop, and demonstrate feasibility of refractive NMBS waveguides for improved optical performance, to include designs for improved steering while minimizing total optical path length. Designs for packaging of such a device should also be considered, taking into account thermal management and optical coupling of remoted lasers. An assessment of whether the proposed technology functions in reverse, as a scannable receiving optic, should be included. The Phase I effort will include prototype plans to be developed under Phase II. A schedule and explanation of the manufacturing readiness level shall be included in the Phase I final report.

PHASE II: Develop a packaged NMBS prototype device from the proposed design. Demonstrate that it is capable of maintaining stable operating temperature while meeting radiant power and M2 requirements. Include, in this demonstration, provisions to steer, either simultaneously or in rapid sequence, multiple wavelengths in the MWIR band. Ensure that volume and electrical power requirements apply to the prototype device.

PHASE III DUAL USE APPLICATIONS: Perform final testing the packaged NMBS device in a relevant environment, to include appropriate integration as applicable to the specific Navy platform. Transition and integrate to an airborne platform of interest chosen in consultation with PMA-272.

This technology is beneficial for medical diagnostics, chemical sensing, and other applications that utilize mid-infrared spectroscopy. Additionally, non-traditional beam steering may have lidar applications if the technology transitions the wavelength used in the lidar system.

REFERENCES:

1. Frantz, J.A.; Myers, J.D.; Bekele, R.Y.; Spillmann, C.M.; Naciri, J.; Kolacz, J.; Gotjen, H.G.; Nguyen, V.Q.; McClain, C.C.; Shaw, L.B. and Sanghera, J.S. "A chip-based non-mechanical beam steerer in the midwave infrared." *Journal of the Optical Society of America B*, 35(12), 2018, pp. C29-C37. <https://doi.org/10.1364/JOSAB.35.000C29>
2. Myers, J.D.; Frantz, J.A.; Spillmann, C.M.; Bekele, R.Y.; Kolacz, J.; Gotjen, H.; Naciri, J.; Shaw, B. and Sanghera, J.S. "Refractive waveguide non-mechanical beam steering (NMBS) in the MWIR [Paper presentation]." *Proceedings of SPIE OPTO 10539, Photonic Instrumentation Engineering V*, San Francisco, CA, United States, January 27-February 1 2018. <https://doi.org/10.1117/12.2290379>

KEYWORDS: non-mechanical; directed energy; lidar; mid-infrared; quantum cascade laser; beam steering; NMBS

N211-006

TITLE: Improving Performance of Solid Rocket Fuel through Advancements in Materials Science

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Materials / Processes; Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design and develop efficient near-throat controlled cooling technologies that would improve solid fuel performance by enhancing condensation of gaseous metal suboxides.

DESCRIPTION: Typically, solid rocket fuel is packed in a tubular motor case and consists of hydroxyl-terminated polybutadiene (HTPB) mixed with fuel additives in the form of metal powders, such as aluminum or boron. Upon deployment of a missile, the available fuel is ignited; and the combustion pressure that develops is funneled through the nozzle assembly. The throat, a critical component of the nozzle, is located near the exhaust end of the motor case. The nozzle diameter is intentionally reduced here in order to alter the flow and maximize performance.

The science of combustion of a solid fuel system is highly complex and it is believed that complete combustion of metal additives could dramatically increase performance [Ref 1]. A substantial part of combustion energy is released during condensation of the gaseous metal suboxides. A significant portion of this energy can be emitted as a flux of light. It could constitute more than 50% of the overall energy produced during the combustion of metals [Ref 4]. This energy should be dissipated from the condensation zone in order to enhance condensation. The thermal conductivity [Ref 5] and jetness of the nozzle are major parameters that control the rate of energy dissipation.

The condensation of metal suboxides occurs concurrently with the exhaust gas expansion in the nozzle. As such, the latter should be thoughtfully designed in order to:

- (a) enable the most favorable conditions for condensation of gaseous metal suboxides into its condensed oxide form,
- (b) accommodate the majority of condensation energy, and
- (c) withstand a radiative heat flux of high intensity formed as a result of a localized light emission subsequent to condensation of gaseous metal suboxides.

This SBIR topic seeks to design and develop efficient near-throat controlled cooling technologies that enhances heat removal, and therefore enhances condensation of gaseous metal suboxides. The manufacturing materials of the nozzle assembly must be able to withstand temperatures of combustion gasses on the order of 3000 K, high-radiative heat fluxes (greater than 10 MW/m² [Ref 8]) caused by intense emissions of light, erosion, stress, thermal shock [Refs 2, 3], and other factors involved in the operation of a solid fuel rocket engine. The legacy materials are mostly based on specialty carbons, such as a carbon-carbon composite, or isostatically molded graphite [Refs 6, 7]. The proposed solution must meet all of the properties of the standard carbon materials to include, but not be limited to, withstand erosion, stress, and thermal shock. Additionally, the throat insert must have controlled material properties

such as thermal conductivity and jetness, so that it can remove heat from the condensing gas and from associated light emission at an ultrahigh rate, at least 10% more efficiently than the traditional materials.

PHASE I: Design and develop a numeric model for the purpose of tuning the throat nozzle assembly's material properties to induce a more efficient condensation near the throat. Initial prefeasibility studies with newly fabricated materials should be undertaken at the bench scale level. Deliver a prefeasibility report that outlines the results from the model and the delineation of nozzle assembly properties, which should at the very least, meet the performance characteristics of existing standard throat nozzle assembly materials at the end of Phase I. Outline a plan for improvement of material properties. Include prototype plans to be developed under Phase II.

PHASE II: Demonstrate that the new materials will be at least 10% more efficient at withdrawing heat from condensing gases and light emission sources. Qualitative modeling will be used to estimate exactly how the prototype parts would benefit the thrust. All other physical and chemical properties of throat assembly will be at the same performance level as standard throat assembly materials. Perform testing to validate the technology can withstand stress, shock, and erosion.

PHASE III DUAL USE APPLICATIONS: Finalize and mature the technology for transition and integration into surface-to-air and air-to-surface munitions, mobile targets, and space vehicle programs. Solid rocket fuel engines are heavily employed by various branches of the U.S. Navy, other branches of the DoD, and NASA to include commercial space exploration missions. Other applications include, but are not limited to, industrial uses for high-density electrically conductive graphite used in refractories, reactor components, and specialty liners for chemical vessels. Another application would be in industrial burners and in the design of exhaust of elevated temperature combustion engines, to include automotive applications.

REFERENCES:

1. Balas, S. and Natan, B. "Boron oxide condensation in a hydrocarbon-boron gel fuel ramjet." American Institute of Aeronautics and Astronautics, Inc., Journal of Propulsion and Power, 32(4), February 24, 2016, pp. 967-974. <https://doi.org/10.2514/1.B35928>
2. Essel, J.T.; Acharya, R.; Sabourin, J. L.; Zhang, B.; Kuo, K. K. and Yetter, R. A. "High-temperature behavior of graphite under laser irradiation." International Journal of Energetic Materials and Chemical Propulsion, 9(3), January 2010, pp. 205-218. <https://doi.org/10.1615/IntJEnergeticMaterialsChemProp.v9.i3.20>
3. Thakre, P.; Rawat, R.; Clayton, R. and Yang, V. "Mechanical erosion of graphite nozzle in solid-propellant rocket motor." American Institute of Aeronautics and Astronautics, Inc., Journal of Propulsion and Power, 29(3), May 7, 2013, pp. 593-601. <https://doi.org/10.2514/1.B34630>
4. Altman, I.S.; Pikhitsa, P.V. and Choi, M. "Key effects in nanoparticle formation by combustion techniques." Springer, Dordrecht, Gas Phase Nanoparticle Synthesis, January 2004, pp. 43-67. https://doi.org/10.1007/978-1-4020-2444-3_3
5. Altman, Igor. "On energy accommodation coefficient of gas molecules on metal surface at high temperatures." Elsevier B.V., Surface Science, August 2020, p. 698. <https://doi.org/10.1016/j.susc.2020.121609>
6. "Technical Data Sheet CGW™ Graphite." GrafTech International Holdings, Inc., 2011.
7. Albers, T.; Miller, D.J.; Lewis, I.C.; and Ball, D.R. "Low CTE Highly Isotropic Graphite (U. S. Patent 7,658,902 B2)." <https://pdfpiw.uspto.gov/.piw?Docid=7658902&idkey=NONE&homeurl=http%3A%252F%252Fpatft.uspto.gov%252Fnetathtml%252FPTO%252Fpatimg.htm>
8. Cross, P.G. "Radiative heat transfer in solid rocket nozzles." Journal of Spacecraft and Rockets 57(2), October 2018, pp. 1-14. <https://doi.org/10.2514/1.A34598>

KEYWORDS: rocket nozzle insert; carbon-carbon composite; isostatically molded graphite; metal combustion; nozzle expansion; condensation efficiency

N211-007

TITLE: Hyperspectral Sensor Metamaterial Lens in Imaging Applications

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments; Electronics; Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design, build, and demonstrate on-chip hyperspectral focal plane array, with integration of dynamically tunable metamaterial lens to perform and produce 2D spatial images with a single exposure at a few selected wavelength bands instead of 1D spatial and all spectral band images.

DESCRIPTION: Hyperspectral imagery (HSI) provides the means to detect targets smaller than the size of a pixel using spectral unmixing techniques. HSI contains hundreds of bands of spectral information per pixel. HSI is traditionally performed using a dispersive (prism or grating) reimaging system with a slit and focal plane array (FPA) at the conjugate image planes. Current HSI state-of-the-art detectors are based on various photon-to-electron conversion principles that, at best, have quantum efficiencies (QE) of 40 percent in the blue spectrum. Since the conversion process is substantially less than unity, additional laser power is required from the transmitter to make up for the loss of signal on the detector. If a photo detector type material with near unity QE could be used, the HSI system performance would dramatically increase with no additional laser power. The very high efficiency of metamaterial photodetectors will dramatically increase the electrical power available for electric small Unmanned Air Vehicle (UAV). Improvements in photo detection efficiencies are sought to advance the tactical capabilities of HSI systems used on UAVs.

Optical metamaterials with negative refractive index behavior have extraordinary promise in HSI applications. Unlike a conventional lens, a negative refractive index implies that when a material refracts an incoming light ray, the refracted ray will be deviated at a negative angle to the normal according to Snell's law. This seemingly trivial observation has profound consequences: focusing can be accomplished by a slab of material instead of a conventionally-shaped lens. More subtly, lenses made from negative index metamaterials (NIMs) can be much more compact than curved optical lenses such as cylindrical and aspheric lenses, since wave vector components along the optical axis can be used for imaging. In conventional optics, these components typically decay at distances very close to the lens surface (the near field), and account for a loss of imaging information, and ultimately, resolution. For a NIM, that decaying evanescent wave instead grows, allowing near-field resolution to extend into the far field. Furthermore, a negative index implies that the phase of a wave decreases, rather than advances, through the metamaterial NIM. A material with $n = -1$ can be considered to reverse the effect of propagation through an equivalent thickness of a vacuum. Consequently, NIMs have a potential advantage to form highly efficient low reflectance surfaces by exactly canceling the scattering properties of other materials. If the NIM is isotropic, then these effects occur regardless of the direction of the incident wave.

NIMs require negative values of both the electrical permittivity (ϵ) and magnetic permeability (μ). Negative permittivity is common in metals at optical frequencies, but negative permeability does not occur naturally; therefore, the construction of metamaterials involves engineering an effective negative permeability using nonmagnetic materials. This can be done by including electromagnetically resonant

structures. Optical-frequency resonators are much smaller in scale (< 1 mm), have been recently made with advanced lithographic procedures, and have shown negative index behavior in the visible and near-infrared spectrum. Still, these NIMs are not isotropic as the features are planar, and the index varies with orientation. Additionally, most of them have large optical losses due to the materials that comprise them.

A quick examination of NIM literature reveals that in most cases where a metamaterial lens would be used to create images, the refractive index should be independent of direction of the incoming radiation. Yet, the properties of most NIMs reported in the literature are not randomly dispersed inclusions, are not dependent on random orientation of crystal grains, and are not inherently isotropic in three dimensions.

The primary challenge in NIMs is advancing the diffraction limit in Near Field capabilities to identify a threshold to separate targets from clutter in hyperspectral data idiosyncrasies. Hence, NIM designs need to provide larger phase shifts and reduce aberrations to enable tuning the focal length with adjustable sequential metamaterial lens structures, resulting in low far-field resolution of features beyond the diffraction limit in the visible spectrum. Highly viable/manufacturable single and sequential metamaterial lens designs addressing the 3-12 μm spectral range with a focus on 3-5 and 8-12 microns are a possible solution.

NIM lens system parameters for trade analysis are:

- (a) Operational spectral range @ 3-12 microns;
- (b) Smallest Spectral sampling step @ 1 nm;
- (c) Spectral resolution @ full-width half maximum (FWHM) @ 7–10 nm;
- (d) Spectral Stability @ < 1 nm;
- (e) Wavelength switching speed @ < 2 ms;
- (f) Incidence angle to the Fabry-Perot Cavity @ $< 5^\circ$ (max $< 7^\circ$);
- (g) Average spectral transmission @ > 0.2 ;
- (h) Image size @ 480 x 750;
- (i) Dynamic range @ 10 bit;
- (j) F-number range of the optics @ 4.0 – 16.0;
- (k) Focal length @ 8–25 mm;
- (l) Field of View (FOV) @ $20^\circ \times 30^\circ$;
- (m) Object distance @ 0.05 m – Infinity;
- (n) Operational quantum efficiency @ $> 100\%$ in the 3-12 microns spectral band;
- (o) Noise factor @ < 1.1 ;
- (p) Bandwidth @ > 100 MHz;
- (q) Fast response speed@ (rise time $t_r < 68 \mu\text{s}$);
- (r) Uniform optical quality in terms of refractive index and extinction co-efficient;
- (s) Root Mean Square (RMS) errors below 1×10^{-3} refractive index units (RIU)
- (t) Weight @ < 350 g;
- (u) Thickness @ 0.2 to 0.5 mm (ultrathin with $<$ wavelength (λ) divided by 8 surface flatness);
- (v) Active areas on the order of 1 to 2 inches in diameter; and
- (w) Focusing performance for oblique incidence with an incident angle up to 15 degrees.

PHASE I: Conduct research and experiments to determine potential NIMs for HSI NIM lens and select optimum technical approach using the system parameters for trade. Develop preliminary design and perform detailed analysis for on-chip hyperspectral focal plane arrays, with integration of dynamically tunable NIM lens to allow for spectral reconstruction with a single photodetector; and to be directly integrated with arbitrarily-sized read-out integrated circuits (ROICs) for real-time HSI in-pixel image processing. Preliminary design should also include an integrated/embedded metamaterial structure that can be easily subjected to change in temperature or to stress loads while interrogated by electromagnetic fields. Through experimentation, identify NIM technical risk elements in the HSI metamaterial lens and

provide viable risk mitigation strategies. The Phase I effort will include on-chip hyperspectral focal plane arrays, with integration of dynamically tunable NIM lens prototype plans to be developed under Phase II.

PHASE II: Refine the design based on outcomes of simulated data, boot strap error analysis, tests and customer feedback in Phase I. Develop, demonstrate, and validate an HSI metamaterial lens prototype in the lab, chamber, and/or field. Demonstrate and validate the prototype system with all of the parameters identified in Phase I. Prepare a report that summarizes the experimental evaluation and validation of the performance characteristics of the developed system.

PHASE III DUAL USE APPLICATIONS: Complete prototype hardware that will cover operational spectral range@ 300 – 1200 nm. Fully develop and transition the technology and methodology based on the research and development results developed during Phase II for DOD applications in the areas of UAVs detection and identification, and other anomaly surveillance and reconnaissance applications.

This SBIR topic has direct relevance to commercial private sector airborne remote sensing companies engaged in environmental monitoring, agriculture assessments and exploration of natural resources due to the system's compact form factor, flexible flight profiles and precision identification, and change/anomaly detection.

Lower cost hyperspectral sensors for agriculture, land use, search/rescue, and homeland security could employ this technology. The use of low-cost solution-based metamaterials and their ability to be directly integrated with arbitrarily-sized ROICs results in HSI cameras that can be produced at a small fraction of the cost of traditional camera systems.

REFERENCES:

1. Aieta, F.; Genevet, P.; Kats, M.A.; Yu, N.; Blanchard, R.; Gaburro, Z. and Capasso, F. "Aberration-Free Ultrathin Flat Lenses and Axicons at Telecom Wavelengths Based on Plasmonic Metasurfaces." American Chemical Society, Nano Letters, 12(9), August 15, 2012, pp. 4932-4936. <https://doi.org/10.1021/nl302516v>
2. Aieta, F. Kats, M.A.; Genevet, P. and Capasso, F. "Multiwavelength achromatic metasurfaces by dispersive phase compensation." Science, 347(6228), March 20, 2015, pp. 1342-1345. <https://doi.org/10.1126/science.aaa2494>
3. Capasso, F. "Nanophotonics based on metasurfaces." OSA Technical Digest, Metamaterials & Metasurfaces SW3I.1, CLEO: Science and Innovations 2015, San Jose, CA, United States, May 10-15, 2015. https://doi.org/10.1364/CLEO_SI.2015.SW3I.1
4. West, P.R.; Stewart, J.L.; Kildishev, A.V.; Shalaev, V.M.; Shkunov, V.; Strohkendl, F.; Zakharenkov, Y.; Dodds, R.K. and Byren, R. "All-dielectric subwavelength metasurface focusing lens." Optics Express, 22(21), October 2014, pp. 26212-26221. <https://doi.org/10.1364/OE.22.026212>
5. Zhang, X. and Liu, Z. "Superlenses to overcome the diffraction limit." Nature Materials, 7, June 2008, pp. 435-441. <https://doi.org/10.1038/nmat2141>
6. Jacob, Z.; Alekseyev, L.V. and Narimanov, E. "Optical hyperlens: Far-field imaging beyond the diffraction limit." Optics Express, 14(18), 2006, pp. 8247-8256. <https://doi.org/10.1364/OE.14.008247>
7. Takahashi, S.; Chang, C.H.; Yang, S.Y. and Barbastathis, G. "Design and fabrication of dielectric nanostructured Luneburg lens in optical frequencies." IEEE, 2010 International Conference on Optical MEMS and Nanophotonics, August 2010, pp. 179-180. <https://doi.org/10.1109/OMEMS.2010.5672127>
8. Takahashi, S. "Design and fabrication of micro- and nano-dielectric structures for imaging and focusing at optical frequencies (Unpublished doctoral dissertation)." Massachusetts Institute of Technology, 2011. <http://hdl.handle.net/1721.1/67602>

KEYWORDS: broadband metamaterial; flat lens; photo detector; optics-on-a-chip; ROIC; Hyperspectral Imaging; HIS; NIM; negative index metamaterial

N211-008

TITLE: Tool to Predict Transient Spatial-Temporal Boundary Conditions for Processing Autoclave-cured Composite Parts

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Materials / Processes

OBJECTIVE: Design, develop, and validate an analytical tool to accurately predict the local transient thermal and mechanical boundary conditions during the processing of composite parts within an autoclave.

DESCRIPTION: Autoclaves are widely used to process and cure high quality parts for composite structural components used on aircraft. This high quality is possible due to the autoclave's high internal pressures and ability to apply high temperatures in excess of 350°F such that the intended resin systems can cure. When these assumed conditions are not met, defects such as porosity and poor fiber consolidation occur [Ref 5]. Autoclave systems are designed with these conditions in mind, but since part thickness, tool geometry, and part location can vary from run to run, the local conditions cannot be guaranteed. The conditions within are driven by the capabilities of the autoclave: air temperature, air flow and physical part geometry interaction with the tooling surface and vacuum bagging [Ref 6]. This environment is thus governed by a variety of physical interactions and requires a multiphysics modeling tool to accurately capture the boundary conditions experienced by the composite parts.

Modeling and simulation to predict composite part quality within an autoclave requires a coupling of the local boundary conditions with the mechanics and chemistry going on within the composite. The temperature of the part at the bag as well as the tooling surface is critical to couple with the cure kinetic models [Ref 4]. Boundary conditions are usually assumed in simple models where the air temperature throughout the autoclave is believed homogenous and the part is experiencing perfect hydrostatic pressure regardless of location or tool geometry. Without accurate boundary conditions, anticipating defects or reducing internal stresses and spring-back is very difficult to predict accurately [Ref 1]. Current modeling capabilities often utilize simplistic two-dimensional models or assumed boundary conditions [Ref 7]. The means to expand that to more complex three dimensions are commercially available but limited. Accurate modeling of the environment within the autoclave can be computationally expensive and require responsive software simulation integration to capture multi-physics interactions [Ref 2]. Hybrid models utilize a variety of physics including Computational Fluid Dynamics (CFD) and heat transfer which then feed into the boundary conditions for cure kinetic models. These models also require experimental validation from actual autoclave runs which can be difficult since each commercial autoclave system is unique [Ref 10]. This is where data fusion from in-situ monitoring can be used not only to validate but to tune a model for predicting boundary conditions. The goal of this SBIR topic is to provide a means to integrate both modeling capabilities as either a single tool or an add-on to existing software. This software tool will have validation from real-life autoclave runs and the means to be adapted to various autoclave systems per the user's need.

Many of the current methods for running parts in an autoclave come from simple models, best practices and extensive thermal surveys to confirm that the material has cured as intended. Autoclave runs completed in early acceptance testing feature parts that are outfitted with a multitude of sensors to measure temperatures throughout the part and tool. The temperature and pressure cycle is then adjusted until the desired cure profile is achieved throughout the part. Temperature ramp rates and early cycle dwell periods are critical to removing volatiles from the liquid resin and facilitating flow. Final cure temperatures and duration confirm that the resin has solidified and reached complete cure at every location in the composite part. Design engineers must intelligently place multiple tooling and parts within the autoclave such that the air flow is not blocked [Ref 3]. Any great change to this process must be

preceded with another thermal survey and part inspection teardown. Having a multiphysics software tool capable of modeling the system's boundaries would reduce the amount of expensive autoclave runs needed to start production. It can also provide production lead time flexibility since the operator can intelligently position multiple parts within the autoclave and still achieve the correct cure profile for each. When there are indications from Non Destructive Inspection (NDI), the software can then be run to assess problem areas within the cure as well as provide the operator feedback that the autoclave may be out of its designed thermal and pressure specification. The benefits of this software tool will allow engineers faster entry into production, gain flexibility in production stream through curing various part combinations and more rapidly assess problems that would later manifest themselves as part defects. Software simulation tools will reduce the number of test runs required for opening up a new composite part production run. They will also enable greater production scheduling freedom through process modeling of part layouts within autoclaves, which will make production more adaptive and save scheduling time and thus cost.

PHASE I: Propose a concept of a multiphysics tool that can address the local non-uniform transient thermal and mechanical boundary conditions accounting for conditions within an autoclave. Demonstrate the concept and quantify the effects of non-uniform environmental conditions via a numerical simulation of airflow temperature, pressure and heat transfer for a simple composite part during autoclave processing.

PHASE II: Enhance and develop the proposed concept prototype tool to address the manufacturing of composite parts containing inserts, complex curvatures, and thick laminates exceeding 1.5 inches in thickness. Validate the prototype tool by comparing simulation results to a live autoclave run containing a variety of composite parts and tooling with select geometries. Capture transient thermal and pressure distributions through in-situ monitoring to be then compared to simulation results. Demonstrate the ability to use this prototype tool coupled with a cure kinetics model for a chosen material system. Verify that this prototype tool can be used on a variety of autoclave systems and part/tool load-outs. Provide the developed prototype software tool for the Navy to use.

PHASE III DUAL USE APPLICATIONS: Transition this software tool to the program and production. Optimize this tool for difficult-to-process parts and layouts that have historically hindered production due to defects and warpage from incorrect autoclave heating.

The product outcome of this SBIR topic has extensive applications for companies producing autoclaved composite parts as well as other industrial processes that require the controlled enclosed heating and pressurization of a product. Software simulation tools will reduce the number of test runs required for opening up a new composite part production run. They will also enable greater production scheduling freedom through process modeling of part layouts within autoclaves. This will make production more adaptive and save scheduling time and thus cost. Secondary applications extend to any enclosed processing of a product using convective heating and external pressure. This includes, but is not limited to, heat treatment of metal, ceramic, and glass products as well as baked goods.

REFERENCES:

1. Baran, I.; Cinar, K.; Ersoy, N.; Akkerman, R. and Hattel, J. "A review on the mechanical modeling of composite manufacturing processes." Archives of Computational Methods in Engineering, 24(2), January 20, 2016, pp. 365-395. <https://doi.org/10.1007/s11831-016-9167-2>
2. Dumont, F.; Fröhlingsdorf, W. and Weimer, C. "Virtual autoclave implementation for improved composite part quality and productivity." CEAS Aeronautical Journal, 4(3), September 2013, pp. 277-289. <https://doi.org/10.1007/s13272-013-0072-1>
3. Maffezzoli, A. and Grieco, A. "Optimization of parts placement in autoclave processing of composites." Applied Composite Materials, 20(3), June 2013, pp. 233-248. <https://doi.org/10.1007/s10443-012-9265-8>

4. Mesogitis, T.; Skordos, A. and Long, A. “Stochastic simulation of the influence of cure kinetics uncertainty on composites cure.” *Composites Science and Technology*, 110, April 6, 2015, pp. 145-151. <https://doi.org/10.1016/j.compscitech.2015.02.009>
5. Potter, K. “Understanding the origins of defects and variability in composites manufacture [Paper presentation].” *Proceedings of the 17th International Conference on Composite Materials*. Edinburg, United Kingdom, July 27-31, 2009. <http://www.iccm-central.org/Proceedings/ICCM17proceedings/papers/P1.5%20Potter.pdf>
6. Potter, K.; Campbell, M.; Langer, C. and Wisnon, M. “The generation of geometrical deformations due to tool/part interaction in the manufacture of composite components.” *Composites Part A: Applied Science and Manufacturing*, 36(2), February 2005, pp. 301-308. [https://doi.org/10.1016/S1359-835X\(04\)00150-2](https://doi.org/10.1016/S1359-835X(04)00150-2)
7. Sreekantamurthy, T.; Hudson, T.B.; Hou, T.-H. and Grimsley, B.W. “Composite Cure Process Modeling and Simulations using COMPRO (Registered Trademark) and Validation of Residual Strains using Fiber Optic Sensors [Paper presentation].” 31st Technical Conference of the American Society for Composites (ASC), Williamsburg, VA, United States, September 19-22, 2016. <https://ntrs.nasa.gov/search.jsp?R=20160012030>
8. Svanberg, J. and Holmberg, J. “Prediction of shape distortions, Part I: FE-implementation of a path dependent constitutive model.” *Composites Part A: Applied Science and Manufacturing*, 35(6), June 2004, pp. 711-721. <https://doi.org/10.1016/j.compositesa.2004.02.005>
9. Svanberg, J. and Holmberg, J. “Prediction of shape distortions. Part II. Experimental validation and analysis of boundary conditions.” *Composites Part A: Applied Science and Manufacturing* 35(6), June 2004, pp. 723-734. <https://doi.org/10.1016/j.compositesa.2004.02.006>
10. Weber, T.; Arent, J.-C.; Munch, L.; Duhovic, M. and Balvers, J. “A fast method for the generation of boundary conditions for thermal autoclave simulation.” *Composites Part A: Applied Science and Manufacturing*, 88, September 2016, pp. 216-225. <https://doi.org/10.1016/j.compositesa.2016.05.036>

KEYWORDS: Composites; autoclave; simulation; computational fluid dynamics; heat transfer; processing

N211-009

TITLE: Cyber Protection for Physical Avionics Data Inputs to Navy Platforms

RT&L FOCUS AREA(S): Cybersecurity; General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Battlespace Environments; Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Research and address the holistic cyber threat posed by the transfer of aeronautical data to Navy and United States Marine Corps (USMC) aircraft by taking physical avionics data inputs to the aircraft and developing solutions to harden those input channels, protecting the data from malicious tampering and errant corruption.

DESCRIPTION: Critical aeronautical data is transferred into avionics systems to provide pilot guidance or other information used to influence pilot decisions in the cockpit. This aeronautical data may include the navigation database, vertical obstruction database, flight plans, world magnetic model, maps, and imagery. To prevent malicious tampering of this data, cyber protection needs to be implemented on all physical avionics data inputs in these airborne systems. Currently, minimal cyber-safe mechanisms are offered and only provide protection against errant corruption. No complete cyber protection set exists for the physical avionics data inputs creating a multitude of threat surfaces to be addressed. The Navy must fully identify all threat surfaces and begin to prototype protections against those threats. The following are examples of physical data threat surfaces (but by no means intended to be a complete list):

Corrupt/Invalid Source –involves the data validity of the data sourced by the data provider (Government, industry, or open-sourced); could be a result of any other type of threat surface.

Errant Corruption –a non-intentional data corruption introduced by human or computer error; also the most easily identified by mechanisms such as Cyclical Redundancy Checks (CRCs).

Proposed approaches should include, but not be limited to, a white hat analysis of all physical avionics data inputs to all Navy and USMC aircraft. For each physical avionics data input this research should identify the data flow which includes data source, transitional systems (e.g., tablet, Navy/Marine Corps Internet (NMCI), Joint Mission Planning Software (JMPS), maintenance computer), and end use. For each data flow, perform a human factors assessment to determine if the pilot decision making based on operational conditions (e.g., instrument flight rules (IFR) vs visual flight rules (VFR), approach vs cross country) and alteration of data inputs can be altered. Potential mitigation strategies should be identified for each physical avionics data input. These mitigation strategies could be process, software, or hardware solutions depending on the scenario. An evaluation of current protections, postulate new or enhanced cyber protections, and perform experimentation to determine if protections are sufficient to mitigate risk should be performed. All postulated solutions should focus on performance of the solution to prevent unnecessary burden on the aircrew that could prevent them from attaining mission success.

Utilizing the white hat analysis, firms should develop prototype solutions for the two platforms with the largest threat surface in order to provide a formal design, implementation, and formal qualification testing

of protection strategies for the data chain from source to end use. Prototype solutions in this context could be hardware, software, and/or procedural guidance. To validate the initial threat surface analysis and protections implemented provide sufficient protections to avert any corrupt/invalid source, errant corruption, Denial of Service (DoS), or spoofing/hacking attack types, potential technologies will participate in a focused ethical hacking event (or Hack-a-thon). A successful demonstration of the prototype solutions would be the prevention of all attempts to infiltrate the system and successful identification and notification of operators of hazardously misleading information that would affect decisions within the cockpit.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Determine feasibility of proposed approach by performing a white hat analysis of all physical avionics data inputs to all Navy aircraft. Provide a summary of the white hat analysis, a listing of all threat surfaces, the affected aircraft, mitigation strategies, and residual risk while also identifying gaps where analysis was non-deterministic. In the Phase I option, if exercised, develop a threat brief deployable to each platform and a Business Case Analysis (BCA). The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and demonstrate prototyping solutions for the two platforms with the largest threat surface. Provide a formal design, implementation, and formal qualification testing of protection strategies for the data chain from source to end use. Prototype solutions in this context could be hardware, software, and/or procedural guidance.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Finalize prototype solutions and validate at a focused ethical hacking event (or Hack-A-Thon). Proofing of threat patches, if high priority topics are discovered, additional or iterative hacking events may occur to ensure completion of targeted topics (i.e., fly-fix). Transition and integrate the deployment of cyber protection strategies to naval platforms or Programs of Record.

The outcome of this topic will result in a packaged set of methodologies to protect data in transit from off-aircraft maintenance stations to on-aircraft usage to protect against both errant and malicious corruptions. Those methodologies could in turn be documented and shared with the private sector for use on Navy projects. Both the commercial sector (such as GE, Jacobs, Raytheon, Rockwell Collins, L3Harris) and other DoD services could benefit from a deployed base cyber protection suite of tools. Software, hardware, and procedural solutions would need to remain portable to multiple environments to support reuse of tools and methodologies.

REFERENCES:

1. "DO-200B, Standards for Processing Aeronautical Data. Radio Technical Commission for Aeronautics." June 18, 2015. https://my.rtca.org/nc_store?search=DO-200B
2. "DO-201B, User Requirements for Navigation Data. Radio Technical Commission for Aeronautics." December 13, 2018. https://my.rtca.org/nc_store?search=DO-201B

KEYWORDS: cyber; collision avoidance; obstacle; database; Hazardously Misleading Information; HMI; safety; cyber protection; corrupt/invalid source; errant corruption

N211-010 TITLE: Cloud Based Air Traffic Control Training System

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments; Human Systems

OBJECTIVE: Develop an innovative and cost-effective Cloud Based Air Traffic Control Training System that can provide ready relevant training and encourage student participation through gamification of learning arcade style activities, with integrated student and class metrics that can increase training efficiency can address that need. This capability will provide a level of training fidelity that the community has not experienced while reducing training time and cost.

DESCRIPTION: Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources. Those resources include networks, servers, storage, applications, and services. These resources can be rapidly provisioned and released with minimal management effort or service provider interaction. Available on-demand, cloud environments are scalable and allow agencies to provision resources as required.

This SBIR topic seeks to investigate a Cloud Based Air Traffic Control Training System that leverages ready relevant learning and game theory. The system should allow remote access to a wide range of exercises and resources for students, instructors, and management. Consistent with the Cloud First policy, agencies will use cloud infrastructure when planning new mission and support applications. Additionally, agencies will consolidate existing applications to help reduce training time. In addition, one of the focus areas is improving training quality.

Ready Relevant Learning (RRL) is about driving fundamental changes into our approach to Sailor training. The goal of RRL is to provide the right training at the right time in the right way. To accomplish this, the Navy will modernize training to maximize impact and relevance, and accelerate processes for delivering new training to the Fleet. In order to improve Sailor performance and enhance mission readiness, the Navy's industrial-era, conveyer-belt training model will transform into a modern version. The modern version will contain content that meets Fleet-validated learning needs [Ref 7].

Gamification [Ref 5] is the process of defining the elements that make games fun and motivate players to continue playing while using those same elements in a non-game scenario to influence behavior [Ref 4]. For an educational scenario, some examples of gamification of desired student behavior include attending class, focusing on meaningful learning tasks, and taking initiative [Ref 6].

Some elements of games that may be used to motivate learners and facilitate learning include, but are not limited to:

- (a) progress mechanics (points/badges/leaderboards);
- (b) narrative and characters;
- (c) player control;
- (d) immediate feedback;
- (e) opportunities for collaborative problem solving;
- (f) scaffolded learning with increasing challenges;
- (g) opportunities for mastery, and leveling up; and
- (h) social connection.

The Cloud Based Air Traffic Control Training System should consist of networked Tower and Radar Trainer, and a Part-task computer-based trainer that has access to training modules on the cloud. More specifically, this effort seeks to investigate a Cloud Based Air Traffic Control Training System allowing

remote access to a wide range of exercises and resources for students, instructors, and management. The system should have the ability to remotely observe the simulator from anywhere in the world via the internet providing users the ability to simulate, simultaneously, operations of multiple Air Traffic Control (ATC) facilities such as multiple ATC approach control radars and multiple ATC towers operating in one given airspace. This ability should allow tower and radar controllers to simultaneously train using the same aircraft, handoffs, etc. to allow for a more realistic training scenario. Interactive development tools that allow for quick and easy creation of accurate scenarios can be immediately deployed to the cloud and used in full simulators and part-task trainers in all locations. Ready Relevant training via flexible part-task trainers that can be adapted to any curriculum aspect to provide targeted in-class training and off-class self-training reinforcement in all stages of student development for immediate implementation via the cloud trainer shall encourage student participation through gamification of learning arcade style activities with competitive scoreboards. If accessible via Department of the Navy (DON) networks, the Navy Marine Corps Intranet (NMCI), the Outside Continental United States (OCONUS) Navy Enterprise Network (ONE-Net), and the Marine Corps Enterprise Network (MCEN), comprehensive class, student, and exercise management tools, exercises and databases can be shared with all sites. The system should be able to quickly and easily identify problem topics for individuals and the whole class to effectively target instruction and deploy ATC training software across the enterprise.

PHASE I: Identify and demonstrate feasibility of a Cloud Based Air Traffic Control Training System that leverages RRL and game theory; and simulates, simultaneously, operations of multiple Air Traffic Control (ATC) facilities such as multiple ATC approach control radars and multiple ATC towers, operating in one given airspace. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and demonstrate a functional Cloud Based Air Traffic Control Training System prototype with the ability to communicate via DON networks, the NMCI, the ONE-Net and the MCEN. The prototype of the software technology that considers and adheres to Risk Management Framework guidelines to support cyber-security compliance in a lab or live environment. Install, integrate, test, train, validate, and deliver the Cloud Based Air Traffic Control Training System prototype.

PHASE III DUAL USE APPLICATIONS: Obtain management framework certification for an authority to operate within operational/training systems. Finalize, refine, and integrate the Cloud Based Air Traffic Control Training System and instructional tools within the training system environment. Transition the technology to a Naval Air Station via a Program Office. Examples of commercial industries that could benefit from this cloud based training include commercial airlines and corporate training. This SBIR topic provides benefits to the private sector by opening up a Navy use case for cloud based training. Although cloud based training has been used outside of the DoD, leveraging cloud based training for the DoD will add additional challenges because of network limitations and cyber security requirements. This solution can be used in the defense industry as the foundation for all future cloud based trainers.

REFERENCES:

1. Kent, S. "From cloud first to cloud smart." Federal Cloud Computing Strategy, 2019. <https://cloud.cio.gov/strategy/#procurement>
2. "Cloud smart strategy." United States Department of the Interior. (n.d.) <https://www.doi.gov/cloud/strategy>
3. Bielby, K. "Cloud first gets smart upgrade to remove cyber policy barriers, says OMB." Homeland Security Today.US, September 24, 2018. <https://www.hstoday.us/subject-matter-areas/cybersecurity/cloud-first-gets-smart-upgrade-to-remove-cyber-policy-barriers-says-omb/>
4. Deterding, S.; Dixon, D.; Khaled, R. and Nacke, L. "From game design elements to gamefulness: defining 'gamification' [Paper presentation]." The 15th International Academic MindTrek Conference, Tampere, Finland, September 28-30, 2011. <https://doi.org/10.1145/2181037.2181040>

5. Merriam-Webster. (n.d.). Merriam-Webster.com dictionary. Retrieved May 21, 2020, from <https://www.merriam-webster.com/dictionary/gamification>
6. Borys, M. and Laskowski, M. "Implementing game elements into didactic process: A case study (Conference session)." 2013 Management, Knowledge and Learning International Conference (MakeLearn), Zadar, Croatia, June 19-21, 2013. https://www.researchgate.net/publication/260060814_Implementing_game_elements_into_didactic_process_a_case_study
7. Davidson, P.S. "Vision and guidance for ready relevant learning: Improving sailor performance and enhancing mission readiness." United States Fleet Forces Command, August 2017. <https://www.public.navy.mil/netc/rrl/documents/Vision-and-Guidance.pdf>

KEYWORDS: Air Traffic Control; Cyber; Cloud-based Training; Training System; Ready Relevant Learning; RRL; Game Theory; gamification; air traffic control; ATC

N211-011 TITLE: Ping Strategies for an Intelligent Search using Multistatic Active Sonar

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop ping strategies, in a simulation environment, that provide optimized performance for multistatic active sonar fields with a target that actively seeks to evade detection by the sonar field.

DESCRIPTION: One of the challenging components for developing new sonar systems and improvements to them is collecting data so that the system is mature with robust performance in a wide variety of acoustic environments. Execution of data gathering events requires large investments funding Navy personnel and assets. In order to reduce costs while developing a system, the Navy seeks to employ models and simulations to the maximum extent possible reducing the need for a large number of data gathering events.

This SBIR topic seeks to develop foremost ping strategies and signal and information processing techniques to optimize search performance that can be validated against a realistic target motion model in a simulation environment. Development of the target motion model is required and that model should include techniques for the target to avoid detection when located in a multistatic active coherent (MSAC) wide area search field. Real-world parameters such as the sound speed profile and bathymetry will be provided. A reactive target model that seeks to evade an active multistatic field and remain undetected will enable more meaningful simulation results of the ping strategies under evaluation and will better demonstrate the effectiveness of the proposed changes. Historical approaches to the detection problem [Ref 7] focus on reconciling the sonar equation. The Navy seeks to develop ping strategies that leverage signal and information processing or other techniques in addition to just reconciling the sonar equation that will improve the probability of detection and show an improvement against a reactive target model that is able to maneuver, change speed, and change depth. Because the target has mass (i.e., the size of a manned platform), instantaneous changes in speed or direction should not be considered in the target motion model.

Work produced in Phase II may be classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly known as Defense Security Service (DSS). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Demonstrate the feasibility of ping strategies for a notional multistatic sonar system, which improves performance against an optimized reactive target model. Show that these new strategies improve performance versus a random ping schedule. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and implement ping strategies for a simulated MSAC field with a reactive target including broadband and narrowband waveforms, multiple input multiple output (MIMO) pinging, and high-duty cycle (HDC) pinging. Demonstrate that new ping strategies can successfully detect a reactive target 25% more often than simple ping schedules.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Finalize and implement the capability as part of an operational sonar system. Transition of this capability should utilize the Advanced Product Builds (APB) process. The search techniques developed under this effort have application across the Navy for sonar, radar, electro-optic, and other sensor devices.

The searching or tracking of mobile targets where the sensors are stationary would benefit from this capability (i.e., tracking assets in an urban battlefield). A potential commercial application would be to the gaming industry especially if the object of the game was to avoid detection or capture.

REFERENCES:

1. Jackson, P. "Introduction to Expert Systems (3rd ed.)." Addison Wesley, 1998. ISBN 978-0-201-87686-4. <http://www.pearsoned.co.uk>
2. Pike, J. and Sherman, R. "Run Silent, Run Deep." Federation of American Scientists, December 8, 1998. <https://fas.org/man/dod-101/sys/ship/deep.htm>
3. Gilliam, C.; Angley, D.; Williams, S.; Ristic, B.; Moran, B.; Fletcher, F. and Simakov, Sergey. "Covariance Cost Functions for Scheduling Multistatic Sonobuoy Fields [Paper presentation]." International Conference on Information Fusion, Cambridge, UK, July 10-13, 2018. https://www.researchgate.net/publication/325597536_Covariance_Cost_Functions_for_Scheduling_Multistatic_Sonobuoy_Fields
4. Kaelbling, L.P.; Littman, M.L. and Moore, A.W. "Reinforcement Learning: A Survey." Journal of Artificial Intelligence Research, 4, May 1, 1996, pp. 237-285. <https://doi.org/10.1613/jair.301>
5. François-Lavet, V.; Henderson, P.; Islam, R.; Bellemare, M. and Pineau, J. "An Introduction to Deep Reinforcement Learning." Foundations and Trends in Machine Learning, 11(3-4), December 20, 2018, pp. 219-354. <https://doi.org/10.1561/22000000071>
6. DoD 5220.00-M: National Industrial Security Program Operating Manual. Department of Defense, February 28, 2006. <https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>
7. Urick, R.J. "Principles of Underwater Sound (3rd ed.)." Peninsula, 2013. ISBN 9780932146625. <https://peninsulapublishing.com/product/principles/>

KEYWORDS: multistatics; intelligent search; evasive target; Multiple Input Multiple Output; MIMO; ping strategies; cost functions

N211-012 TITLE: Micro-Electromechanical Gyroscope for Improved Inertial Navigation Systems Performance

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Battlespace Environments; Electronics

OBJECTIVE: Design and develop a miniature, low-cost, high-performance inertial navigation system based on novel micro-electromechanical system (MEMS) gyroscope technology for improved performance and Space, Weight, Power, and Cooling (SWaP-C).

DESCRIPTION: The Department of the Navy (DON) has emphasized the need for aerial platforms to have GPS-independent position, navigation, and timing capability. In order to satisfy the position and navigational capability goals, more advanced inertial navigation systems (INS) are needed. Inertial measurement units (IMUs) based on MEM technology could be the key to obtaining this sought after INS capability. MEMS gyroscopes are gaining increased usage in commercial and military applications because of their low size, weight, and power characteristics; MEMS-based IMUs that are shock/vibration resistant have the potential to provide accurate GPS-independent position and navigation data. Recent advances in the construction of MEMS devices have made it possible to manufacture small and light IMUs. Improvements in MEM gyroscope technology include characteristics such as bias drift prediction, micro-capacitance sensing, structure-borne noise and vibration analysis, quality factor optimization, bandwidth expansion, data compensation, quadrature error correction, and ease of fabrication. The availability of new MEMS, such as the Double U-beam vibration ring gyroscope (DUVRG), have the potential to improve unaided INS performance while retaining the ability to operate in the harsh environments common to Navy aviation platforms. A number of DUVRG structures can be combined into a small area, with opposing temperature and noise sensitivities to offset errors, and their outputs averaged for improved drift rates. The Navy seeks vibration and shock resistant tactical grade IMU for inertial navigation that are less than 3 in³, (volume), 100g (weight), and 2.3W (power) with position/angle/angle rate errors of 0.2m/0.1°/.005° per hour or less. This SBIR topic seeks vibration and shock [Ref 1] resistant tactical grade IMU for inertial navigation that are less than 3 in³, (volume), 100g (weight), and 2.3W (power) with position/angle/angle rate errors of 0.2m/0.1°/.005° per hour or less.

PHASE I: Demonstrate feasibility of the MEM gyroscope technology, including the use of DUVRGs in the design of a robust INS with state-of-the-art unaided drift characteristics. Determine how much improvement in position, pointing, roll and pitch accuracy can be obtained using advanced MEM gyroscope technology, and begin designing a DUVRG-based (or other innovative MEM gyroscope) INS using modeling and/or analysis. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate, and validate a DUVRG-based or other innovative MEM gyroscope-based INS prototype. Perform bench level tests to verify the performance of prototype. Assess performance in a representative environment using MIL-STD-810 [Ref 1].

PHASE III DUAL USE APPLICATIONS: Complete development of a MEM gyroscope-based INS prototype and demonstrate performance in an actual, operational environment. Integrate and transition to Navy hosting platforms. This technology would benefit any organization (i.e., space launch vehicles, commercial driver less vehicles, Merchant Marine vessels, and civilian aircraft) seeking a means of long term navigation without GPS.

REFERENCES:

1. "MIL-STD-810H, Department of Defense Test Method Standard: Environmental Engineering Considerations and Laboratory Tests (January 31, 2019)." Department of Defense. http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL_STD_810H_55998/
2. Gallacher, B.J. "Principles of a micro-rate integrating ring gyroscope." IEEE Transactions on Aerospace and Electronic Systems, 48(1), 2012, pp. 658-672. <https://doi.org/10.1109/TAES.2012.6129662>
3. Cao, H.; Liu, Y.; Kou, Z.; Zhang, Y.; Shao, X.; Gao, J.; Huang, K.; Shi, Y.; Tang, J.; Shen, C. and Liu, J. "Design, fabrication and experiment of double U-beam MEMS vibration ring gyroscope." Micromachines, 10(3), 186, 2019. <https://doi.org/10.3390/mi10030186>
4. Mayberry, C.L. "Interface circuits for readout and control of a micro-hemispherical resonating gyroscope (Doctoral dissertation, Georgia Institute of Technology)." <https://smartech.gatech.edu/bitstream/handle/1853/53116/MAYBERRY-THESIS-2014.pdf>
5. Kou, Z.; Liu, J.; Cao, H.; Feng, H.; Ren, J.; Kang, Q. and Shi, Y. "Design and fabrication of a novel MEMS vibrating ring gyroscope [Paper presentation]." 2017 IEEE 3rd Information Technology and Mechatronics Engineering Conference (ITOEC), Chongqing, China, October 3-5, 2017. <https://doi.org/10.1109/ITOEC.2017.8122396>
6. Xia, D.; Yu, C. and Kong, L. "The development of micromachined gyroscope structure and circuitry technology." Sensors, 14(1), January 14, 2014, pp. 1394-1473. <https://doi.org/10.3390/s140101394>

KEYWORDS: Alternative GPS; micro-electromechanical system; MEMS; gyroscope; inertial navigation; inertial navigation system; INS; drift rates; Inertial measurement units

N211-013 TITLE: Cooling Devices for Helmeted Maintainers, Flight Deck Crew, and Rotary-Wing Aircrew

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Biomedical; Human Systems

OBJECTIVE: Design and develop a thermoregulatory control device to be worn in conjunction with maintainer, flight deck crew, and rotary-wing aircrew helmets to prevent overheating in hot climates and support continued mission operation without degradation in human performance for up to twelve hours.

DESCRIPTION: Helmet systems have been developed to improve hearing and head protection in extremely loud environments [Refs 1-2]. Most of these helmets are unvented and some have an edge roll seal around the face and neck to improve hearing protection. Consequently, these features also create the potential for increased risk of overheating while wearing the helmet, especially in hot environments, over a 12-hour work period [Refs 3-4].

The Department of the Navy (DoN) seeks thermoregulatory control devices to be worn in conjunction with maintainer, flight deck crew, and rotary-wing aircrew helmets. The proposed technology must prevent the potential overheating of maintainers, flight deck crew, and rotary-wing aircrew for up to 12 hours [Refs 5-7]. Cooling devices may be head, neck, or body mounted and worn in, or under, the current helmet system or clothing. The technology must not interfere with mission operation, nor should it cause a decline in human performance or hearing protection over a 12-hour period. Technologies must be portable, lightweight, and should integrate with current helmets or personal protective equipment without disruptions to the edge roll or shell of the helmet, which would degrade current levels of hearing protection. In addition, added weight on the head should not significantly change the center of mass so as to lead to discomfort or decreased performance, nor should the technology force the head into a forward pitch position. The desired system may include, but is not limited to, passive and active, evaporative, conductive, or convective cooling. The technology should have minimal components and no risk of accidental detachment during mission operations. The cooling must not introduce health or safety risks to the warfighter or the environment. Both a one-size-fits-all approach, as well as, specific solutions for each application will be considered.

Although not required, it is highly recommended to work in coordination with the original equipment manufacturer (OEM) to ensure proper design and to facilitate transition of the final technology [Refs 1-2].

NAVAIR will provide Phase I performers with the appropriate guidance required for human research protocols so that they have the information to use while preparing their Phase II Initial Proposal. Institutional Review Board (IRB) determination as well as processing, submission, and review of all paperwork required for human subject use can be a lengthy process. As such, no human research will be allowed until Phase II and work will not be authorized until approval has been obtained, typically as an option to be exercised during Phase II.

PHASE I: Develop approaches to an innovative cooling solution that does not compromise hearing or head protection. Demonstrate proof of concept through test fixture testing and modeling. The Phase I effort will include prototype plans to be developed under Phase II.

Note: Please refer to the statement included in the Description above regarding human research protocol for Phase II.

PHASE II: Develop and produce a prototype thermoregulatory device based on the design developed in Phase I. Perform subject testing to evaluate performance in work-representative scenarios. Develop life-cycle costs and supportability estimates.

Note: Please refer to the statement included in the Description above regarding human research protocol for Phase II.

PHASE III DUAL USE APPLICATIONS: Develop an optimized solution, finalize testing efforts, and assist in transitioning the technology to the fleet. Provide the Navy with all mechanical and electrical drawings associated with production representative solutions.

Developed technology could be used commercially in the utilities sector, sports industry, or any instance in which helmeted personnel require cooling solutions to maintain a sustained activity level.

REFERENCES:

1. Navy SBIR (2004.3). Advanced Helmet for Maintainer Head and Hearing Protection. <https://www.sbir.gov/sbirsearch/detail/1515545>
2. “Gentex Aircrew Rotary Wing Helmet Systems.” Gentex Corporation (2020, June 12). <https://www.gentexcorp.com/>
3. Rodahl K., Guthe T. and Morrison, J.B. (ed). “Physiological limitations of human performance in hot environments, with particular reference to work in heat-exposed industry.” Taylor & Francis, Environmental Ergonomics—Sustaining Human Performance in Harsh Environments, 37, February 1, 1988,, pp. 22-69. ISBN-10: 0850664004. <https://www.amazon.com/Environmental-Ergonomics-Igor-B-Mekjavic/dp/0850664004>
4. Tharion, W.J.; Goetz, V. and Yokota, M. “Estimated metabolic heat production of helicopter aircrew members during operations in Iraq and Afghanistan.” No. T12-03. Army Research Institute of Environmental Medicine, Natick, MA, January 2012. https://www.researchgate.net/publication/277753739_Estimated_Metabolic_Heat_Production_of_Helicopter_Aircrew_Members_during_Operations_in_Iraq_and_Afghanistan
5. “Chapter 3: Prevention of heat and cold stress injuries (ashore, afloat, and ground forces).” Manual of Naval Preventive Medicine (NAVMED P-5010-3).”, Bureau of Medicine and Surgery, Washington, DC, February 12, 2009. <http://www.navybmr.com/study%20material/NAVMED%20P-5010/5010-3.pdf>
6. “Chapter B2: Heat stress.” Navy Safety and Occupational Health Program Manual for Forces Afloat. (OPNAVINST 5100.19F). Office of the Chief of Naval Operations, May 5, 2019. <https://www.secnave.navy.mil/doni/Directives/05000%20General%20Management%20Security%20and%20Safety%20Services/05-100%20Safety%20and%20Occupational%20Health%20Services/5100.19F.pdf>
7. “Chapter 8: Thermal Stress Program.” Safety and Environmental Health Manual. (COMDTINST M5100.47), February 27, 2019. https://media.defense.gov/2019/Mar/01/2002094847/-1/-1/0/CIM_5100_47C.PDF

KEYWORDS: thermoregulatory; overheating; evaporative cooling; conductive cooling; convective cooling; cooling devices

N211-014 TITLE: Predictive Model Based Control System for High Speed Dynamic Airframe Testing

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop a scalable, real-time, predictive, and adaptive model-based test frame control system that increases load cycling frequency while maintaining load accuracy for high speed dynamic rotary wing airframe testing.

DESCRIPTION: Full-scale fatigue testing is required for all new aircraft designs. While all aircraft are subjected to this testing, rotary wing aircraft often prove to be much more difficult to evaluate because of the high cycle counts that helicopter airframes experience. Currently, the limitations of structural testing control systems require full-scale fatigue tests to be performed at frequencies much lower than those generally experienced on rotary wing aircraft. Full-scale fatigue testing on rotary wing aircraft is typically limited to a low cycle fatigue test, where Ground-Air-Ground cycles and simplified maneuver loads are applied to the airframe. Truncation and/or equivalent damage methods are used to reduce the cycle count in order to perform a test within a reasonable time period. However, there is evidence that shows that equivalent damage methods, which remove high frequency load components at high mean stress loads, can produce unconservative crack growth rates. The crack growth rates are slower than what would be accumulated on an in-service aircraft, which creates a risk of not being able to find premature cracking at a representative time, or even at all during the full-scale fatigue test. Since pure cycle count reduction cannot produce test results that are consistent with real fleet usage, increasing testing speed is required to be able to incorporate more loading cycles without significantly prolonging a test effort.

Current technology used in full-scale fatigue testing is limited to load cycle speeds of approximately 2 Hz, and most tests are practically slow enough to be considered quasi-static. At speeds this low, full-scale fatigue tests would take over 200 years to complete if all vibratory load content were to be included. The control system generally used for this testing is a reactive-style feedback loop that requires a load to be applied, usually by means of hydraulic servo-cylinders, and the system response to be read by sensors, such as strain gauges and load cells. Gains in the feedback loop are adjusted to provide satisfactory tracking between the target and measured loads or strains. While these reactive methods are adequate for quasi-static tests, they become insufficient as the frequency and speed of the test increases due to complexities caused by large airframe displacements, airframe inertial effects, actuator cross coupling, and phase lag caused by system response times. If these issues are unaddressed, the load cycling rate in a test will have to remain low in order for loads to be applied accurately. Accurate loads are required to attain representative test results to ultimately make a correct assessment of the actual life of the airframe, as well to catch and predict early cracking that might occur in the fleet.

This SBIR topic seeks a model-based, or “model-in-the-loop”, control system for full-scale aircraft fatigue testing that can achieve higher cycling rates and faster test speeds compared to those achievable by current reactive control systems (0.5 Hz – 2 Hz). The control-system should be able to predict and generate the signals required for load application based on sensor data (including strain gauge bridges, load cells, displacement transducers) and a representative model of the system. This model could include the test article, fixtures, actuators, hydraulic valves and supply system, and sensors located on the test article or on the actuators. A peak loading frequency of at least 10 Hz is desired in order to match the primary loading frequencies on rotary-wing platforms. The control system should be capable of controlling high speed actuators that can achieve speeds in excess of 100 in/s in order to meet or exceed the frequency requirement while still being able to achieve displacements that may be several inches in magnitude. The controller should be able to simulate the test system in real time, use the model to predict

required actuation signals, adapt the model and parameters to account for nonlinearities and uncertainties, and be scalable to handle multiple degrees of freedom with coupled actuators with potential for 15 or more actuators.

Commercial and naval aircraft both face similar requirements for full scale fatigue testing. Improvements to testing speed while maintaining required loads and displacements would improve both cost and schedule for acquisitions and validation of new platforms. This technology could also improve dynamic testing in automotive applications, as well as for other ground-based military vehicles.

PHASE I: Determine feasibility of a real-time, predictive, and adaptive control system using a simplified test setup that leverages models of the test system in order to increase variable amplitude load accuracy at higher frequencies. Develop a plan for expanding the Phase I work into a prototype system that can be demonstrated on a simplified test article capable of increased test speeds and controlling multiple actuators.

PHASE II: Develop and demonstrate a prototype model-based control system based on the Phase I approach by integrating the controller into a test that applies representative loads onto simplified test article that is representative of an airframe structure in order to show increased control system performance (i.e., speed and accuracy) against a traditional control system. Demonstrate the ability to handle the coupling of multiple actuators as seen in a full scale fatigue test.

PHASE III DUAL USE APPLICATIONS: Develop and demonstrate a modular and scalable model-based control system on a full scale fatigue test specimen using multiple actuators and combined vibratory/maneuver loading. Verify that the system can apply vibratory loads accurately at load cycling rates of 10 Hz or higher.

Because commercial and naval aircraft both face similar requirements for full scale fatigue testing, improvements to testing speed while maintaining required loads and displacements would improve both cost and schedule for acquisitions and validation of new platforms. This technology could also improve dynamic testing in automotive applications and for other ground-based military vehicles.

REFERENCES:

1. Plummer, A.R. "Model-in-the-Loop Testing." Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering, 220(3), 2006, pp. 183-199. <https://doi.org/10.1243/09596518JSCE207>
2. Hewitt, R.L. and Albright, F.J. "Computer modeling and simulation in a full-scale aircraft structural test laboratory." ASTM International, Applications of Automation Technology to Fatigue and Fracture Testing and Analysis: Third Volume, 1997, pp. 32-33. <https://doi.org/10.1520/STP11542S>
3. Mare, J.-C. "Dynamic loading systems for ground testing of high speed aerospace actuators." Aircraft Engineering and Aerospace Technology, 78(4), July 1, 2006, pp. 275-282. <https://doi.org/10.1108/17488840610675546>
4. Plummer, A.R. "Control techniques for structural testing: a review." Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering, 221(2), March 2007, pp. 139-169. <https://doi.org/10.1243/09596518JSCE295>
5. Cornelis, B.; Toso, A.; Verpoest, W. and Peeters, B. "Adaptive modelling for improved control in durability test rigs [Paper presentation]." Proceedings of the 20th International Congress on Sound and Vibration (ICSV 20), Bangkok, Thailand, July 7-11, 2013, pp. 507-516. https://www.researchgate.net/publication/258440444_Adaptive_Modelling_for_improved_control_in_durability_test_rigs

6. Sarhadi, P. and Yousefpour, S. “State of the art: hardware in the loop modeling and simulation with its applications in design, development and implementation of system and control software.” *International Journal of Dynamics and Control*, 3(4), June 10, 2014, pp. 470-479.
<https://doi.org/10.1007/s40435-014-0108-3>
7. Hu, J. and Plummer, A.R. “Compensator design for model-in-the-loop testing [Paper presentation].” 2016 UKACC 11th International Conference on Control (CONTROL), Belfast, Northern Ireland, United Kingdom, August 31-September 1, 2016.
<https://doi.org/10.1109/CONTROL.2016.7737633>

KEYWORDS: Control; Dynamic; Testing; Structure; Predictive; Adaptive

N211-015 TITLE: Long-Wave Infrared Transceivers for High Speed Free Space Optical Communications in Adverse Weather Conditions

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop long-wave infrared transceiver components with high-data rate and low-bit error rate for use in free-space optical communications in adverse weather conditions.

DESCRIPTION: Free-space optical (FSO) communication links provide high-data rate, low latency, secure wireless, mobile communication that are difficult to jam or intercept and do not require spectrum management. FSO communication is an especially compelling alternative to a radio-frequency (RF) link with external RF Interference (RFI) in a RF-denied environment. Most current proposed or deployed FSO systems are in the short wave Infrared (SWIR) regime at around 1.55 micrometers due to ubiquity of the laser and optical components customized for fiber optical communications. Exceptionally high data rates at this wavelength range are possible when atmospheric effects are not present [Ref 1], and laser-based FSO communication is the leading solution for interconnecting new constellations of low-earth-orbit satellites. Terrestrial FSO links have seen some success, but link budget in the SWIR regime is often limited by optical obscurants such as haze, fog, clouds, atmospheric absorption, and turbulence presence in the atmosphere. SWIR links with stabilized telescopes have been demonstrated to achieve gigabit per second (Gb/s) communication between naval vessels in ship-to-ship and ship-to-shore configurations at ranges of 12 and 45 kilometers (km) [Ref 2], despite the link limitation to 1 km when the visibility was impaired by heavy fog. For FSO laser communications systems operating in the SWIR bands, including 1300 nm and 1550 nm, the photonic wavelength is comparable to the size of aerosols that scatter and attenuate the laser beam propagation in the channel.

Recent analysis has shown that operation in a more optimal long wave infrared (LWIR) wavelength range accessible from monolithic sources only via Quantum Cascade Lasers (QCLs) enables dramatically lower attenuation from a variety of atmospheric effects [Ref 3]. The attenuation due to the presence of optical obscurants, such as fog, haze, and maritime aerosols for 10-micrometer (μm) wavelength transmission, is strikingly over 300 times lower than that at 1550 nm. Furthermore, LWIR FSO communication link at 10 μm wavelength have much reduced Rayleigh scattering compared to the 1.55 μm counterpart. At the same time, the fast carrier dynamics of QCLs make high-speed direct modulation possible [Ref 4], thereby also reducing transmitter complexity.

The main goal of this SBIR topic is to develop the LWIR transceiver, including the laser for the transmitter and detector for the receiver to leverage the unique LWIR atmospheric transmission window that is more transparent than other wavelengths in adverse weather conditions. The adverse weather condition is defined as the atmospheric conditions where a 1.55 μm FSO link would suffer > 25dB attenuation due to multiple scattering caused by various hydrometeor types such as haze, clouds, fogs, and aerosols such as dusts, smoke, and pollens [Ref 1]. Current Fabry-Perot (FP) QCLs emitting in the 10-micron regime provide less than 1W single-facet continuous wave (CW) power with less than 5% efficiency [Ref 5]. Large QCLs have modulation bandwidths that are limited by the large device capacitance. Commercial distributed feedback (DFB) QCLs in this wavelength range emit less than 100 milliwatts, potentially limiting the FSO link budget. Innovative QCL designs are needed to increase the QCL room temperature CW output power while maintaining beam quality ($M^2 < 1.5$) and high reliability for the LWIR FSO system.

The Threshold and Objective parameters of QCL, detectors, and the transceivers are as follows:

- QCL CW max power: Threshold of 250 mW, Objective of 1000 mW

- QCL wavelength: Threshold of 8.5-12 micron, Objective of 9.5-11.5 micron
- QCL linewidth: Threshold of 10 nm, Objective of < 2 nm
- Detector detectivity: Threshold of $D^* 2.25E9 \text{ cm}^* \text{ SQRT(Hz)/W}$, Objective of $5E9 \text{ cm}^* \text{ SQRT(Hz)/W}$
- Detector quantum efficiency: Threshold of 10%, Objective of 50%
- Data rate (worse case conditions): Threshold of 1 Gb/s, Objective of 10 Gb/s
- Data rate (clear conditions): Threshold of 10 Gb/s, Objective of 40 Gb/s
- Average transmitter power: Threshold of 125 mW, Objective of 500 mW
- Receiver sensitivity at $1E-12$ bit error rate (BER): Threshold of -18 dBm, Objective of -25 dBm
- Receiver saturation: Threshold of 1 mW, Objective of 10 mW

Cost-effective FSO links must function with devices' temperatures near ambient (25 degrees C) to minimize cooling system cost, size, and power. At these temperatures, thermally induced dark current unacceptably limits detectivity of conventional LWIR photodetectors needed for the receiver side of the FSO link. Reducing detector volume reduces the dark current, but also the area and responsivity. Recent research has shown that metal and dielectric resonators can enhance the collection area and responsivity, enabling high detectivity in the LWIR near room temperature [Ref 6]. High detectivity has been demonstrated in devices based on both inter-band and inter-subband absorption, but innovative designs are certainly required to achieve both high speed and high receiver sensitivity simultaneously.

FSO links based on LWIR QCLs and detectors operating at wavelengths optimized for highest system level performance will enable secure, mobile, naval communications in RF congested and denied environments. With the successful development of these critical LWIR components, a cost-effective and low space, weight, and power (SWaP) digital communication link that supports encryption with effective range over 100 km will be the objective of future development.

PHASE I: Design, develop, and demonstrate LWIR lasers and detectors needed for 10 Gb/s transmission for the adverse weather conditions [Ref 1]. The design should include plans for growth, fabrication, packaging processes, and a monolithic QCL transmitter emitting in the 10-micron wavelength region capable of 1W single facet CW operation and direct modulation bandwidth > 5 GHz. Detectors should have commensurate performance to enable the 10 Gb/s link. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate, and validate a prototype FSO link operating in the 10-micron region with at least 10 Gb/s data rate and BER of $1E-12$ with 1 W average, single-spatial-mode transmitter launch power for the adverse weather conditions. Perform testing to explore the limits of operational speed and distance. Provide a production cost model.

PHASE III DUAL USE APPLICATIONS: Finalize development of the prototype based on Phase II results for transition and integration into a Navy operational test asset. Conduct risk management and mitigation.

Telecommunications and local, urban communications (communication nodes – line of sight) would benefit from this technology due to its high bandwidth capability even in adverse weather conditions.

REFERENCES:

1. Rensch, D.B. and Long, R.K. "Comparative studies of extinction and backscattering by aerosols, fog, and rain at 10.6 μm and 0.63 μm ." Applied Optics, 9(7), 1970, pp. 1563-1573.
<https://doi.org/10.1364/AO.9.001563>

2. Corrigan, P.; Martini, R.; Whittaker, E.A. and Bethea, C. “Quantum cascade lasers and the Kruse model in free space optical communication.” *Optical Society of America, Optics Express*, 17(6), 2009, pp. 4355-4359. <https://doi.org/10.1364/OE.17.004355>
3. Bai, Y.; Bandyopadhyay, N.; Tsao, S.; Slivken, S. and Razeghi, M. “Room temperature quantum cascade lasers with 27% wall plug efficiency.” *Applied Physics Letters*, 98, 181102, May 2, 2011. <https://doi.org/10.1063/1.3586773>
4. Lee, B.G.; Belkin, M.A.; Audet, R.; MacArthur, J.; Diehl, L.; Pflüegl, C.; Capasso, F., Oakley, D.C.; Chapman, D.; Napoleone, A.; Bour, D.; Corzine, S.; Höfner, G. and Faist, J. “Widely tunable single-mode quantum cascade laser source for mid-infrared spectroscopy.” *Applied Physics Letters*, 91(23), December 3, 2007, pp. 231101-1–231101-3. <https://doi.org/10.1063/1.2816909>
5. Hofstetter, D.; Graf, M.; Aellen, T.; Faist, J.; Hvozdar, L. and Blaser, S. “23GHz operation of a room temperature photovoltaic quantum cascade detector at 5.35 μ m.” *Applied Physics Letters*, 89(6), August 10, 2006, pp. 061119-1–061119-3. <https://doi.org/10.1063/1.2269408>
6. Palaferri, D.; Todorov, Y.; Bigioli, A.; Mottaghizadeh, A.; Gacemi, D.; Calabrese, A.; Vasanelli, A.; Li, L.; Davies, A.G.; Linfield, E.H.; Kapsalidis, F.; Beck, M.; Faist, J. and Sirtori, C. “Room-temperature nine- μ m-wavelength photodetectors and GHz-frequency heterodyne receivers.” *Nature*, 556, March 26, 2018, pp. 85–88. <https://www.nature.com/articles/nature25790>
7. Rodriguez, E.; Mottaghizadeh, A.; Gacemi, D.; Palaferri, D.; Asghari, Z.; Jeannin, M.; Vasanelli, A.; Bigioli, A.; Todorov, Y.; Beck, M.; Faist, J.; Wang, Q.J. and Sitori, C. “Room-Temperature, Wide-Band, Quantum Well Infrared Photodetector for Microwave Optical Links at 4.9 μ m Wavelength.” *ACS Photonics*, 5(9), 2018, pp. 3689-3694. <https://doi.org/10.1021/acsp Photonics.8b00704>

KEYWORDS: long wave infrared; LWIR; photonics; lasers; photodetector; Free-space Optical; FSO Communications; adverse weather

N211-016

TITLE: Lightweight Thermal Protection System for Hypersonic Aerial Vehicles

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a lightweight, high-performance, thermal protection system for hypersonic aerial vehicles operating in hypersonic flight environments.

DESCRIPTION: Hypersonic aerial vehicles have more aerodynamic shapes with sharp leading edges to improve performance. When a vehicle is travelling through the atmosphere at hypersonic speeds of Mach 5 or higher, it encounters intense friction with the surrounding air. The nose cone and the leading edges of the flight vehicle will experience extremely high temperatures up to 3000 to 5000 degrees Fahrenheit (F). The extreme temperature of the leading edge caused by the kinetic heating is inversely proportional to the square root of its radius of curvature [Ref 1]. Therefore, the more aerodynamic the shape of the vehicle, the higher the temperatures of the leading edges.

Ultra-high temperature ceramics (UHTCs) materials, such as Hafnium carbide and Tantalum carbide [Ref 2], have extremely high melting points and high resistance to oxygen-induced ablation. Additionally, active research has been performed to develop these types of ceramics materials with mechanically and thermally robust structural and coating materials for hypersonic vehicles. Besides the thermal challenges of hypersonic vehicle exteriors, the extreme heat from the high-temperature external surfaces transported to the interior of the vehicle can impact performance and reliability of the internal systems, avionics and payloads.

This SBIR topic seeks to address the vehicle's interior high-temperature challenges by developing and creating a lightweight, high-performance, materials and cooling system to insulate the exterior high temperature from the interior of the hypersonic vehicle. Any innovative passive or active thermal protection solution will be considered as long as it will maintain the internal ambient temperature of a hypersonic aerial vehicle at no more than 110 °F and the total weight is no more than 15% of the hypersonic aerial vehicle when empty [Ref 3]. The final hypersonic aerial vehicle shape and form will be determined at the beginning of the Phase I.

PHASE I: Design, develop, and demonstrate feasibility of the proposed lightweight thermal protection system for the hypersonic aerial vehicles. Conduct analytical and experimental models of the design. Determine any technical risks of the design and provide risk mitigation strategy. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Fully develop and optimize the approach developed in Phase I. Validate the lightweight thermal protection system's performance via testing in a relevant representative hypersonic environment. Demonstrate that the lightweight thermal protection system can meet the performance requirements stated

in the Description in a high-fidelity simulated aerothermodynamics heating for hypersonic flight environments [Ref 4].

PHASE III DUAL USE APPLICATIONS: Finalize development, based on Phase II results, for transition and integration of the product into a hypersonic vehicle candidate airframe. Conduct flight test units for fielding on Navy experimental flight tests.

This system could be applied to any commercial air vehicle, which must fly at high supersonic-to-hypersonic speeds (space access and recoverable vehicles). In addition, any low cost, high-temperature materials capable of surviving in a high-supersonic-flight environment would have diverse application in other industries that have components exposed to high temperatures, such as automotive engines, industrial processes, aircraft engines, airliner fuselages, industrial furnaces and confined electronics. Finally, the product could also be used as a cryogenic insulation for liquid natural gas fuel storage tanks or other kinds of cryogenic liquids.

REFERENCES:

1. Lewis, M.J. "Sharp Leading Edge Hypersonic Vehicles in the Air and Beyond." SAE International, SAE 1999 Transactions, 108, October 19, 1999, pp. 841-851. <https://doi.org/10.4271/1999-01-5514>
2. Cedillos-Barraza, O.; Manara, D.; Boboridis, K.; Watkins, T.; Grasso, S.; Jayaseelan, D.D.; Konings, R.J.M.; Reece, M.J. and Lee, W. E. "Investigating the highest melting temperature materials: A laser melting study of the TaC-HfC system." Scientific Reports, 6, 37962, December 1, 2016. <https://doi.org/10.1038/srep37962>
3. "High-Speed Strike Weapon To Build On X-51 Flight" Archived January 4, 2014, at the Wayback Machine. Aviation Week, 20 May 2013.
4. Mueschke, N. (n.d.). "Hypersonic Flight Test." Southwest Research Institute. <https://www.swri.org/industry/hypersonics-research/hypersonic-flight-test>

KEYWORDS: hypersonics; thermal protection materials; thermal protection systems; hot structures; high temperature materials; air vehicles; aerial vehicles

N211-017

TITLE: Sonobuoy Improvements for Multistatic Active Sonar

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop improvements for active sonar search detection, classification, and localization performance by using or adding non-acoustic sensors to sonobuoys.

DESCRIPTION: Air ASW multistatic active sonar detection, classification, and localization (DCL) performance relies on advanced processing algorithms to exploit transmitted and received sonobuoy signals. The uncertainty surrounding these signals place fundamental limits on system performance and mission success.

The Navy seeks to upgrade or add non-acoustic sensing hardware to sonobuoys which will measurably improve DCL or tracking performance for active sonar (threshold 10% improvement over a sonobuoy without the capability, objective 25% improvement), particularly for scenarios where GPS is not available. An ideal solution will be low cost (adding less than \$50.00 to the cost of a production sonobuoy), fit within the existing sonobuoy size (i.e., cylinder of diameter 4 7/8 inches, length 36 inches), weight (i.e., not cause a sonobuoy to exceed a maximum of 39 lbs) and power (SWaP) constraints (ideally a sensor requiring less than 12 volts and 25 milliamps), and be capable of improving several performance metrics.

Proposed solutions should identify the sonobuoy(s) to be upgraded, the performance metrics expected to benefit from the proposed sensor hardware improvements, and quantify the expected improvement through simulation and/or experiments. Sonobuoy improvements may consider adding transducers and/or replacing existing ones. Examples of such include, but are not limited to, buoy localization performance could potentially be improved by adding/replacing sensors to increase accuracy of time-of-flight and/or bearing measurements. Temperature and/or salinity sensors could be added to provide a partial sound speed profile for individual buoys. Sensors such as inertial measurement units (IMU), gyroscopes, and accelerometers could be used for motion compensation.

Work produced in Phase II may be classified. Note: If the work is classified then, the prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Demonstrate feasibility of the proposed concept through analysis, simulation, and real-world measurements where possible. Analysis should include estimating the bounds of performance for the proposed method, and potential impacts to the existing sonar system operation. Conduct trade-offs of SWaP versus performance improvements for different sensing strategies. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Refine the concept and develop prototype sonobuoys with improved sensing. Evaluate the improvements using at sea experiments. Develop processing software for using the new sensors either aboard an aircraft or embedded in the sonobuoy.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Finalize and implement the capability into a sonobuoy that can be deployed in an open ocean environment during a data gathering event conducted by the Navy. Analyze the data collected in this real-world environment event and verify that the realized gains in performance matched the expected gains.

The technology developed under this effort has application across the Navy for sonar, radar, electro-optic, magnetic anomaly detection and other sensor devices. Any commercial application that uses sensors whose positions need to be known with more precision would benefit from this effort. A possible commercial application could include improved sensor positions during medical imaging procedures.

REFERENCES:

1. Reynolds, S.A.; Flatté, S.M.; Dashen, R.; Buehler, B. and Maciejewski, P. "AFAR measurements of acoustic mutual coherence functions of time and frequency." The Journal of the Acoustical Society of America, 77(5), May 1985, pp. 1723-1731.
<https://asa.scitation.org/doi/pdf/10.1121/1.391921>
2. Kirk, J.C. "Motion compensation for synthetic Aperture Radar." IEEE Transactions on Aerospace and Electronic Systems, AES-11(3), May 1975, pp. 338-348.
<https://doi.org/10.1109/TAES.1975.308083>
3. Hayes, M.P. and Gough, P.T. "Synthetic aperture sonar: A review of current status." IEEE Journal of Oceanic Engineering, 34(3), July 2009, pp. 207-224.
<https://doi.org/10.1109/JOE.2009.2020853>
4. "DoD 5220.22-M National Industrial Security Program Operating Manual (Incorporating Change 2, May 18, 2016)." Department of Defense.
<https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>

KEYWORDS: sensor position; position uncertainty; sonobuoy positions; sensor movement compensation; Detection, Classification, Localization; DCL; sonar sensors; sonobuoy

N211-018

TITLE: Non-Traditional Airborne Anti-Submarine Warfare (ASW) System

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design and develop a non-traditional airborne Anti-Submarine Warfare (ASW) system capable of detecting modern quiet submarine targets from high altitude aircraft.

DESCRIPTION: Detection of operational modern-day submarines is becoming increasingly complex due to advances in submarine technologies. Acoustic signature detection is the traditional method in use today. For fixed-wing aircraft, those systems employ expendable sensors - sonobuoys - to enable detection of the submarine's acoustic signals. The Navy would like to explore alternate, non-traditional concepts that overcome the detection limitation, in order to expand the tools available to operating forces and develop potentially more robust systems.

The principal fixed-wing ASW aircraft in operation today is the P-8 Poseidon. Any new approaches to airborne ASW will eventually require compatibility with that airframe. Also, the acoustic sensors used today are expendable devices. Testing will include hardware in-the-loop or laboratory modeling. Finally, any new approaches should not be considered a replacement for existing systems but as a supplement to expand airborne surveillance capabilities to detect those submarines, surfaced or submerged, with enhanced covert technology.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA), formerly the Defense Security Service (DSS). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Develop and demonstrate feasibility of a non-traditional concept for an airborne ASW system that detects targets through exploitation of novel target/environment interactions. Consider the operating platform's capabilities and limitations for guidance for the overall and ultimate system proposed. Provide sufficient detail to identify the concept (e.g., history, components, effects, hardware). The Phase I effort will also include prototype plans to be developed under Phase II.

PHASE II: Identify critical technology areas requiring validating experimental data. Working with the Navy, define testable hypotheses and identify test equipment and geometries necessary to collect the

critical data, which could also involve analysis of any existing data, building software/hardware fabrication, and potential laboratory experimental measurements. Demonstrate the prototype system and perform analysis as applicable.

Work in Phase II may become classified. Please see note in Description paragraph.

PHASE III DUAL USE APPLICATIONS: Complete final testing and perform necessary integration and transition for use in ASW and countermine warfare, counter surveillance, and monitoring operations with appropriate current platforms and agencies, and future combat systems under development. Commercially this product could be used to enable remote environmental monitoring such as in oil, gas and mineral industries, and in geophysical survey, facilities, and vital infrastructure assets.

REFERENCES:

1. Moser, P. "Gravitational Detection of Submarines." Warminster, Naval Air Development Center, 1989. <http://www.dtic.mil/dtic/tr/fulltext/u2/1012150.pdf>
2. Skolnik, M. "A Review of NIDAR." Naval Research Laboratory, Washington DC, 1975. <http://www.dtic.mil/dtic/tr/fulltext/u2/b228588.pdf>
3. Stefanick, T. "The Nonacoustic Detection of Submarines." Scientific American, 1988, pp. 41-47. <http://www.nature.com/scientificamerican/journal/v258/n3/pdf/scientificamerican0388-41.pdf>
4. Wren, G. and May, D. "Detection of Submerged Vessels Using Remote Sensing Techniques." Australian Defence Force Journal, 1997, pp. 10-15. <https://fas.org/nuke/guide/usa/slbm/detection.pdf>
5. Godin, O.A. "Anomalous transparency of water-air interface for low-frequency sound." Physical Review Letters, 97(16), 164301, 2006. <https://doi.org/10.1103/PhysRevLett.97.164301>

KEYWORDS: Non-Acoustic; Detection; ASW; Imagery; Magnetics; Algorithm; Radar; Anti-submarine Warfare

N211-019 TITLE: Aging Prediction of Airworthiness of Aircraft Composite Components
Accounting for Flight and Environmental Conditions

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Materials / Processes; Weapons

OBJECTIVE: Develop a data-driven computational framework to enable prediction of material aging for designing a new/replacement composite component or its repair, assessing airworthiness of such a component during its lifetime and for assessing life extension.

DESCRIPTION: A building block approach is typically used in the design of composite material systems and their qualification and certification (Q&C). Knowledge gained by employing analytical models, along with tests at the coupon level, is employed in developing the next level design of structural elements. Similarly, the knowledge gained at the structural elements through computational models and testing enable the development of subcomponents and components [Ref 1].

Composite structures are typically designed to operate at much lower stress levels than their maximum strength and most of the loads are below fatigue threshold. However, history has shown widespread damage to occur towards the end of the designed life. This could very well be due to degradations in the metallic structures with which the composite parts interface in an aging aircraft. It could also be due to the accumulations of in-service overloads, such as flying over the rated G limits or impact loads caused by severe landings, both resulting in flaws that grow with further usage. These reveal the uncertainties and shortcomings of the current design and Q&C's approach in meeting the damage tolerance design requirements, as included in the Joint Services Specification Guide, JSSG2006 [Ref 2].

A novel, computationally efficient framework is sought to accurately assess the structural integrity of individual airframe subjected to realistic flight usage and operating environments [Refs 3, 4, 5]. It should be capable of integrating various aircraft data ranging from flight state parameter history, available Structural Health Monitoring (SHM) sensors (e.g., strain gages, acoustic and/or fiber optic sensors) to airframe configuration, and maintenance and repairs [Refs 5, 6].

The framework should account for, but not be limited to,:

- (a) realistic flight history data of flight conditions;
- (b) the gaps in the data;
- (c) mission specific loading and environmental variability; and,
- (d) identifying potential multiphysics trade-offs to enable accelerated testing.

Some of the composite material systems of Navy's interest are glass fiber reinforced plastic and graphite-epoxy resin systems such as IM7/ 8552, AS4/3501-6, AS4/ IM977-3, and IM7/977-3.

PHASE I: Explore the feasibility of developing a framework for data-driven multiphysics algorithms for predicting the damage tolerance requirements of JSSG2006 for composites, as described above. Include the methodology for testing in-service loading and environmental conditions [Refs 9,10] for validation of the algorithms. Further, include the mechanism for filling gaps in the data for prediction of the airworthiness of composite components. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop the framework and demonstrate it for the platform chosen by the Navy by utilizing realistic flight history data for predicting damage tolerance of the component with specific issues

identified by the Navy. Validate the multiphysics-based algorithms using appropriate tests simulating the in-service loading environment and for different blocks in the building block approach.

PHASE III DUAL USE APPLICATIONS: Apply the framework to the Navy selected platforms by integrating it with the data available from Structural Health Monitoring sensors, if any, and databases providing aircraft history of maintenance, repairs, and structural upgrades. Commercial passenger and cargo airlines could potentially benefit from this technology.

REFERENCES:

1. "MIL-HDBK-17-1F, Composite Materials Handbook: Vol. I. Polymer Matrix Composites Guidelines for Characterization of Structural Materials". U.S. Department of Defense, June 17, 2002. http://everyspec.com/MIL-HDBK/MIL-HDBK-0001-0099/MIL_HDBK_17_1F_237/
2. "Department of Defense Joint Service Specification Guide: Aircraft Structures (JSSG-2006). U.S. Department of Defense, October 30, 1998.. http://everyspec.com/USAF/USAF-General/JSSG-2006_10206/
3. Cortial, J.; Farhat, C.; Guibas, L.J. and Rajashekhar, M. "Compressed sensing and time-parallel reduced-order modeling for structural health monitoring using a DDDAS." Computational science 7th international conference, Beijing, China, May 27-30, 2007, Proceedings, Part I-ICCS 2007: Lecture notes in computer science, Vol. 4487, pp. 1171-1179. https://doi.org/10.1007/978-3-540-72584-8_153
4. Amsellem, D.; Farhat, C. and Lieu, T. "Aeroelastic analysis of F-16 and F-18/A configurations using adapted CFD-based reduced-order models [Paper presentation]." 48th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Honolulu, HI, United States, April 23-26, 2007. <https://doi.org/10.2514/6.2007-2364>
5. Michopoulos J.; Tsompanopoulou P.; Houstis E.; Farhat C.; Lesoinne M.; Rice J. and Joshi A. "On a data-driven environment for multiphysics applications." Future generation computer systems, 21(6), June 2005, pp. 953–968. <https://doi.org/10.1016/j.future.2003.12.023>
6. Molent, L. and Aktepe, B. "Review of fatigue monitoring of agile military aircraft." Fatigue and Fracture of Engineering Materials & Structures, 23(9), September 2005, pp. 767-785. <https://doi.org/10.1046/j.1460-2695.2000.00330.x>
7. Michopoulos, J.; Hermanson, J. and Iliopoulos, A. "Advances on the constitutive characterization of composites via multiaxial robotic testing and design optimization." Advances in computers and information in engineering research, Vol. 1, 2014, pp. 73–95. ASME. https://doi.org/10.1115/1.860328_ch4
8. Seneviratne, W.; Tomblin, J. and Kittur, M. "Durability and residual strength of adhesively-bonded composite joints: The case of F/A-18 A–D wing root stepped-lap joint." Woodhead Publishing, Fatigue and Fracture of Adhesively-Bonded Composite Joints, 2015, pp. 289-320. <https://doi.org/10.1016/B978-0-85709-806-1.00010-0>
9. MIL-HDBK-530-1, Department Of Defense Handbook: "Aircraft Usage and Service Loads Statistics," Volume 1, Criteria and Methodology, 01 July 2019.
10. Nickerson, W.; Amiri, M. and Iyyer, N. "Building environmental history for Naval aircraft." Corrosion Reviews 37, No. 5, 2019, pp. 367-375

KEYWORDS: Composites Design; Aging Aircraft; Structural Health Monitoring; SHM; Fatigue; Repair Design; Qualification and Certification

N211-020 TITLE: Digital Firing Device

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Electronics; Weapons

OBJECTIVE: Design, develop, and demonstrate an innovative digital firing device that will be used as a form, fit, and function interchangeable replacement for the airborne rocket launcher.

DESCRIPTION: The Navy is currently using an intervalometer, which fits inside launchers such as the LAU-68 or LAU-131. The device allows pilots to fire individual rocket tubes in sequential order or ripple-fire an entire launcher within seconds. With limited space, the current design seeks enhancement of power, while accounting for the controlling voltage losses due to ambient circuit resistance to ensure sufficient firing current. The only time power is applied to the circuit is when the pilot pulls the trigger. The desired design needs to use innovative circuit designs to overcome the lack of power needed to maintain the current firing state of the intervalometer when the trigger is released. The lack of power can be overcome by storing information during the power cycle or by other means such as, but not limited to, energy harvesting to provide supplemental power.

The Navy would like to steer away from the current analog device and move to something digital. The Navy is looking for a form, fit, and function innovative replacement that can be used interchangeably with the existing intervalometer and launchers, except that the functionality is expected to be achieved via a digital circuit board design (vice the current analog design). The device should be roughly the size of a small (roughly 8"L x 2"W x 2"H) handheld flashlight. The current device uses a rotating dial, but another means of allowing user input (LOAD/ARM, rocket selection) may be used such as, but not limited to, rotary encoders.

General operation of the intervalometer should provide rocket firing current outputs including, but not limited to,:

- a) input power of 20.0 to 31.5 volts direct current (Vdc), otherwise, in accordance with the dc normal operation characteristics of MIL-STD-704 [Ref 1], is supplied through a 5.0 ohm \pm 10 percent resistor;
- b) control and apply rocket firing current to output pins sequentially;
- c) each rocket firing output pins should be tested using a 4 ohm \pm 10 percent resistor;
- d) rocket firing current pulse measured at each pin should be not less than 1.5 amperes (amps), with the load specified for not less than 10 milliseconds (ms).
- e) interruptions of this power, as a result of any type of contact bounce or switch chatter of 4.0 +/- 0.4 ms duration, should not interfere with the performance of the intervalometer;
- f) the single and ripple modes are controlled by an electrical switch located on the launcher structure; and
- g) interface with the single/ripple switch and identify firing mode prior to operation.

The operation of the digital firing device should be defined in two modes: single mode operation and ripple mode operation. In single mode operation, the intervalometer should apply rocket firing current to only one output pin in sequence with each application of power, and be capable of not less than 12 firings per second. In ripple mode operation the intervalometer ripple rate should be self-generating in such a manner as to apply rocket firing current to output pins in sequential order. The overall firing time in the ripple mode should fire rockets with a minimum delay of 5 ms and a maximum delay of 30 ms with at least a 10 ms dwell time and an output between firing pulses of a minimum 35 ms and a maximum of 45 ms.

Setting the intervalometer to the LOAD position should internally ground all output circuits and prevent the intervalometer from being electrically sequenced upon the application of power. The internal grounding should be accomplished by means of the ground circuit. Upon completion of the last rocket firing, the intervalometer output should sequence to the LOAD position and not sequence any further (i.e., should not return to first rocket) upon the application of power. The arm circuit should provide the ground circuit to all outputs, but should also allow for electrical sequencing upon the application of power. The intervalometer should be manually switched from the LOAD position to the ARM position to provide positive arming of the intervalometer.

The intervalometer should provide a grounding circuit through the intervalometer to ensure safety during loading and preparation. The ground circuit should ground all output pins when the intervalometer is in the LOAD or ARM position. As the intervalometer is electrically advancing through its sequence, the ground circuit should ground each output pin except those being fired. The ground circuit should ground the output pin with a resistance of not greater than 0.1 ohm. If the intervalometer is manually advanced through firing positions to the LOAD or ARM position, all output pins should remain grounded.

The intervalometer should have a settable firing sequence to maintain launcher center of gravity during firing. In the event of a short circuit to ground or an open circuit on the output pins during rocket firing current application, the intervalometer should be fault tolerant and be capable of continuing operation without damage.

PHASE I: Design, develop, and determine feasibility of a proof of concept for the digital firing device. Ensure to account for tube slipping, handling, and manufacturing plans. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype digital firing device, and demonstrate its application in a test rocket launcher (provided as Government furnished equipment (GFE)). If available, demonstrate the capability on existing platform and/or platform representative examples.

PHASE III DUAL USE APPLICATIONS: Perform final development and testing to include conformance testing to applicable MIL-STDs [Refs 1, 2]. Support final system application testing onboard aircraft with full system test, in coordination with NAVAIR Test and Evaluation.

The intervalometer has a potential commercial use in the fireworks industry to sequence the launching of multiple fireworks with a determined time interval. In addition to this commercial use, these intervalometer can be sold to foreign militaries.

REFERENCES:

1. "MIL-STD-704F w/CHANGE 1: Department of Defense interface standard: aircraft electric power characteristics." Naval Air Systems Command, Naval Air Warfare Aircraft Division, Lakehurst, December 5, 2016. http://everyspec.com/MIL-STD/MIL-STD-0700-0799/MIL-STD-704F_CHG-1_55461/
2. "MIL-STD-3018 w/CHANGE 2: Department of Defense standard practice parts management. Department of Defense, Defense Logistics Agency Land and Maritime, June 2, 2015. http://everyspec.com/MIL-STD/MIL-STD-3000-9999/MIL-STD-3018_CHG-2_52157/

KEYWORDS: launcher; intervalometer; firing current; timing delay; relay; rockets

N211-021 TITLE: High-Efficiency Midinfrared LEDs with High Brightness for High-Fidelity Infrared Scene Projection

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop midinfrared light emitting diodes (LEDs) with optical cavities electromagnetically engineered at a subwavelength scale to enhance wall-plug efficiency and brightness of devices beyond the current state-of-the-art technology and to demonstrate multipixel mid-infrared LED arrays.

DESCRIPTION: Efficient light-emitting diodes (LEDs) operating in the midinfrared spectral range, that includes both mid-wave infrared (MWIR) (3-5 micron) and long-wave infrared (LWIR) (8-12 micron) wavelength regions, are highly desired for the use in systems for infrared scene projection (IRSP), chemical sensing, and spectroscopy. Hardware-in-the-loop (HITL) testing of infrared (IR) guided weapons necessitates infrared imagery to provide target signatures with high fidelity in a simulated environment with sufficient brightness. The capability to engage IR weapon and aircraft sensors and seekers with high-brightness, high-definition imagery of targets and backgrounds in HITL simulation is essential in the test and evaluation of the systems, such as threat detection and missile warning systems. Current IR scene projectors based on resistive emitter array technology have performance shortcomings such as low output radiance, slow frame rates, and small frame size. Compared to thermal sources, midinfrared LEDs can offer substantially higher radiance, modulation speeds, and significantly larger frame size over existing technologies. However, current devices are still highly inefficient. External wall-plug efficiency of state-of-the-art MWIR LEDs is currently below 0.5% at room temperature [Refs 1, 2] and that of LWIR LEDs is at least one order of magnitude lower [Ref 3].

Low wall-plug efficiency leads to low brightness of MWIR and LWIR LED systems. Low efficiency and brightness of midinfrared LEDs primarily result from a combination of low internal quantum efficiency (IQE) of light generation and low light extraction efficiency. IQE is limited by rapid non-radiative carrier recombination, which is dominated by strong Auger recombination at high pump currents [Ref 4]. As a result, IQE is estimated to be approximately 10% in the state-of-the-art MWIR LEDs operating around 3 microns [Ref 2] and drops quickly at longer wavelengths. For LWIR LEDs, IQE is well below 1% [Ref 4]. Furthermore, mid-infrared LEDs suffer from low extraction efficiency at 2% resulting from a narrow total internal reflection cone in LED materials [Ref 1, 2]. Parasitic voltage drops in the semiconductor heterostructure also have a negative effect on the midinfrared LED efficiency, although this factor has relatively minor effect compared to the two factors mentioned above [Refs 2, 3].

Electromagnetic engineering of LED optical cavities at a subwavelength scale can dramatically enhance light emission in the near- and far-infrared bands [Refs 5, 6, 7]. Subwavelength LED cavities can produce strong Purcell enhancement of spontaneous emission rates, which leads to drastic improvements in IQE, and enables optimal radiative emission rates of the photons in the cavity mode to free space, which improves output efficiency [Refs 5, 6, 7].

This SBIR topic seeks to investigate if similar approaches may dramatically enhance midinfrared LED efficiency and to demonstrate high-performance midinfrared LED arrays based on this technology. Proposed approaches should design, fabricate, and characterize midinfrared LEDs with optical cavities electromagnetically engineered at a subwavelength scale to enhance wall-plug efficiency and brightness of devices beyond the current state of the art. The threshold and final objective wall-plug efficiencies of this MWIR LED arrays are 10% and 15%, respectively. Multipixel LED arrays based on this technology for high-fidelity, HITL testing should be demonstrated.

PHASE I: Design, develop, and demonstrate the feasibility of brightness and wall-plug efficiency enhancement of midinfrared LEDs using subwavelength optical cavity structuring to enhance spontaneous light emission rates into the LED material and out-coupling rates of light from the LED material to free space. The Phase I effort will include prototype plans to be developed in Phase II.

PHASE II: Fabricate and characterize a single element midinfrared LED prototype, with wall-plug efficiency at room temperature. Based on the new LED geometry, demonstrate feasibility of fabricating multipixel LED arrays. Fabricate and completely characterize the prototype with a 64x64 pixel addressable LED array. Prepare a report that summarizes the experimental evaluation and validation of performance characteristics of the developed system.

PHASE III DUAL USE APPLICATIONS: Fully develop and transition a 512x512 pixel addressable LED array-based dynamic IR scene projector per specifications based on the research and development of results developed during Phase II for DoD applications.

This type of high brightness, high-fidelity infrared scene projectors can be used as HITL testing of thermal imaging cameras used by firefighters. In direct projection, images are projected directly into the camera; in indirect projection, images are projected onto a diffuse screen, which is then viewed by the camera. These high performance LED-based scene projectors can also be used in virtual reality for testing of IR search, track and rescue operations systems, and calibration for any spectrally sensitive IR remote sensing instrument.

REFERENCES:

1. Meyer, R.J.; Bewley, W.W.; Merritt, C.D.; Kim, M.; Kim, C.S.; Warren, M.V.; Canedy, C.L. and Vurgaftman, I. "Mid-infrared interband cascade light-emitting devices with improved radiance [Paper presentation]." Proceedings of the SPIE OPTO: Quantum Sensing and Nano Electronics and Photonics XV, San Francisco, CA, United States, 10540, 1054009-1, January 27-February 1, 2018. <https://doi.org/10.1117/12.2288009>
2. Ermolaev, M.; Lin, Y.; Shterengas, L.; Hosoda, T.; Kipshidze, G.; Suchalkin, S. and Belenky, G. "GaSb-Based Type-I Quantum Well 3–3.5- μm Cascade Light Emitting Diodes." IEEE Photonics Technology Letters, 30(9), May 1, 2018, pp. 869-872. <https://doi.org/10.1109/LPT.2018.2822621>
3. Das, N.C.; Bradshaw, J.; Towner, F. and Leavitt, R. "Long-wave (10 μm) infrared light emitting diode device performance." Solid-State Electronics, 52(11), November 2008, pp. 1821-1824. <https://doi.org/10.1016/j.sse.2008.09.003>
4. Krier, A. "Physics and technology of mid-infrared light emitting diodes." Philosophical Transactions of the Royal Society A, 359(1780), March 15, 2001, pp. 599-618. <https://doi.org/10.1098/rsta.2000.0745>
5. Hoang, T.B.; Akselrod, G.M.; Argyropoulos, C.; Huang, J.; Smith, D.R. and Mikkelsen, M.H. "Ultrafast spontaneous emission source using plasmonic nanoantennas." Nature Communications, 6, 7788, July 27, 2015. <https://doi.org/10.1038/ncomms8788>
6. Akselrod, G.M.; Argyropoulos, C.; Hoang, T.B.; Ciraci, C.; Fang, C.; Huang, J.; Smith, D.R. and Mikkelsen, M.H. "Probing the mechanisms of large Purcell enhancement in plasmonic nanoantennas." Nature Photonics, 8, October 14, 2014, pp. 835-840. <https://www.nature.com/articles/nphoton.2014.228>
7. Madeo, J.; Todorov, Y.; Gilman, A.; Frucci, G.; Li, L.H.; Davies, A.G.; Linfield, E.H.; Sirtori, C. and Dani, K.M. "Patch antenna microcavity terahertz sources with enhanced emission." Applied Physics Letters, 109(14), 141103, October 4, 2016. <https://doi.org/10.1063/1.4963891>

KEYWORDS: Electromagnetic Engineering; high-efficiency; midinfrared; light emitting diode; LED; high brightness; infrared scene projection; mid-wave infrared; MWIR

N211-022 TITLE: High Performance Continuous Wave Quantum Cascade Lasers Immune to Output Facet Optical Damage

RT&L FOCUS AREA(S): Directed energy; Quantum Science

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop high-performance large output aperture mid-wave infrared (MWIR) Quantum Cascade Lasers (QCLs) with a large laser catastrophic optical damage threshold, thereby eliminating QCL failures due to the optical facet damage.

DESCRIPTION: Reliable Quantum Cascade Lasers (QCLs) capable of delivering 10 Watts continuous wave (CW) optical power [Ref 1] with high efficiency are of great interest to the Navy for various naval applications. Current generation devices with continuous wave (CW) output power over 3 Watts generally have a poor long-term reliability. Post-mortem analysis of failed high-power QCLs typically shows catastrophic output facet damage. The damage is strongly correlated with the peak optical intensity at the output facet. A game-changing solution is needed to enable the high-performance QCLs to have long-term reliability and meet/exceed the MILSPEC requirements [Ref 2].

An effective, innovative approach to solving the laser optical damage problem is to reduce optical power density at the output laser facet. For a fixed output power level, this can be attained by judiciously increasing the output aperture size without affecting the diffraction-limited beam quality. This can be achieved by employing a second-order distributed feedback (DFB) configuration where optical output is collected from either the surface or the substrate side of the device, as opposed to the edge of the laser. In this case the output aperture is three orders of magnitude larger than that for edge-emitting QCLs, thereby improving the catastrophic optical damage threshold by more than 1,000 fold. An additional advantage of second order DFB QCLs is that they can be pre-screened on the wafer-level, leading to labor and material saving cost benefits associated with cleaving and testing substandard edge-emitting QCL devices. Also, packaging of surface-emitting devices on submounts is less demanding due to their increased alignment tolerance. Therefore, QCLs with large output aperture and reduced optical power density can provide a significant reduction in price per watt for high power CW QCLs.

Although second order DFB QCLs were demonstrated over a decade ago, their performance significantly lags that for Fabry-Perot devices [Refs 3, 4]. In most explored DFB configurations, the grating interacts with the guided mode along the entire laser cavity. This unavoidably leads to additional optical losses, increasing laser threshold and reducing slope efficiency. This is especially detrimental to CW QCL operation.

This SBIR topic seeks the development of a novel QCL configuration that effectively leverages improvements in CW power and efficiency achieved for state-of-the-art Fabry-Perot QCLs, while at the same time offering the unparalleled reliability advantage due to a significant increase in output aperture size. The final device configuration should be compatible with a large-throughput, low-cost production,

and therefore should not involve epi-growth interruptions. The specifications of the CW QCLs should have a large output aperture size no smaller than 1 millimeter(mm) x 10 micrometers (μm), CW efficiency higher than 20% and output power level higher than 20 Watts delivered in a nearly diffraction-limited beam with $M2 < 1.5$.

PHASE I: Design, document, and demonstrate feasibility of high performance CW QCLs with a large output aperture size (no smaller than 1mm x 10 μm). Demonstrate, using numerical modeling, that projected CW efficiency exceeds 20% and output power level exceeds 20W delivered in a nearly diffraction limited beam with $M2 < 1.5$. Ensure that the approach shows that projected fabrication cost for new devices does not exceed that for state-of-the-art commercial buried heterojunction QCLs. In the Phase I Option, if exercised, carry out proof-of-concept experiments. The approach should show that projected fabrication cost for new devices, does not exceed that for state-of-the-art commercial buried heterojunction QCLs. The Phase I effort will include prototype plans to be developed in Phase II.

PHASE II: Construct, develop, and demonstrate the prototype devices based on the design from Phase I. Test and continually improve QCL performance while demonstrating CW efficiency and power to meet topic requirements. Demonstrate that the QCL devices can operate at full power for over 10,000 hours.

PHASE III DUAL USE APPLICATIONS: Fully develop, fabricate, test, and transition the technology based on the design and demonstration results developed during Phase II for DoD applications in the areas of Directed Infrared Countermeasures (DIRCM), advanced chemicals sensors, and Laser Detection and Ranging (LIDAR). The commercial sector can benefit from this crucial, game-changing-technology development in the areas of detection of toxic gas environmental monitoring, noninvasive health monitoring and sensing, and industrial manufacturing processing.

REFERENCES:

1. Bai, Y.; Bandyopadhyay, N.; Tsao, S.; Slivken, S. and Razeghi, M. "Room temperature quantum cascade lasers with 27% wall plug efficiency." Applied Physics Letters, 98, 181102, May 2, 2011. <https://doi.org/10.1063/1.3586773>
2. "MIL-STD-810H, Department of Defense test method standard: environmental engineering considerations and laboratory tests." Department of Defense, January 31, 2019. http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/
3. Bai, Y.; Tsao, S.; Bandyopadhyay, N.; Slivken, S.; Lu, Q.; Caffey, D.; Pushkarsky, M.; Day, T. and Razeghi, M. "High power, continuous wave, quantum cascade ring laser." Applied Physics Letters, 99(26), 261104, December 28, 2011. <https://doi.org/10.1063/1.3672049>
4. Boyle, C.; Sigler, C.; Kirch, J.; Lindberg, D.; Earles, T.; Botez, D. and Mawst, L. "High-power, surface-emitting quantum cascade laser operating in a symmetric grating mode." Applied Physics Letters, 108(12), 121107, March 24, 2016. <https://doi.org/10.1063/1.4944846>

KEYWORDS: Quantum Cascade lasers; QCL; optical facet; reliability; optical damage; Fabry-Perot; continuous wave

N211-023 TITLE: Collaborative Workspace for Next-Generation Navy Mission Planning System

RT&L FOCUS AREA(S): General Warfighting Requirements; Machine Learning/AI

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a collaborative workspace to integrate the disparate locations where mission planning occurs, and to facilitate the mission planning process within the ready room while maintaining operational security.

DESCRIPTION: In order to greatly improve capability in mission planning, the Next-Generation Navy Mission Planning System (NGNMPS) is tasked to facilitate collaborative mission planning across ready rooms and planning cells both in close proximity and, when applicable, across ready rooms and planning cells that are distant from one another. Unfortunately, the current mission planning process utilizes a single laptop computer that will not suffice for the collaborative mission planning vision. With new technological tools such as tablets, smart boards, and digital touch screen tables, it is necessary to leverage these capabilities to improve the mission planning process. Technical approaches should identify potential solutions to achieve the integration and transfer of unclassified and classified (i.e., Secret) mission planning data. This effort will require a highly innovative approach to develop a solution that is sufficiently secure to meet National Security Agency (NSA) requirements for highly classified communications. Various levels of Emissions Control (EMCON) should be considered in the solution. Evaluations will be based on the ability for a solution to provide connectivity across various hardware (e.g., laptops, tablets, smart boards) from disparate shipboard locations (or even land-to-ship communications, if possible) while maintaining NSA requirements for secure communications in support of air operations mission planning.

Current mission planning processes include calculating or planning data in one location, and then transmitting the information, whether by phone or by hand, to the mission planning lead where it is hand-entered into the current mission planning system. This relay of information can occur over and over again, leading to human errors in communication and increased opportunities for typographical error. The first goal of this project is to integrate the disparate locations where mission planning occurs. This solution will require an innovative solution to move data from the location where it is entered and transmit the data to all mission planning components while maintaining operational security.

A secondary goal of this project is to facilitate the mission planning process within the ready room. The current use of obsolete technology for mission planning, mission briefing, and mission rehearsal are time-intensive, redundant, and prone to human error. Utilizing current state-of-the-art technologies for mission planning will greatly improve the mission planning process. Some of the tools used require time-intensive processes like formatting slides, editing screenshots, and other redundant actions that could be eliminated with improved mission planning and briefing hardware. This second goal should leverage current state-of-the-art technologies including, but not limited to, tablets, smart boards, augmented or virtual reality (AR/VR) devices, and digital touch screen tables. Connectivity between these devices

should consider security and space available on shipboard operations. Finally, working closely with the Strike Planning and Execution Systems Program Management Office (PMA-281), Naval Information Warfare Center – Pacific (NIWCPAC), and the NGNMPS development team, the performers on this project should understand and implement the software and user-experience considerations provided by NGNMPS program management.

To achieve these goals, performers should consider innovative solutions including data fusion or other data consolidation techniques to reduce large amounts of spreadsheet data into smaller, more easily understood formats for briefing. Cognitive psychology, human perception, user interface, and human information processing should be considered when proposing a solution to this topic.

Work produced in Phase II may be classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly known as Defense Security Service (DSS). Since this project will ultimately be integrated into the Consolidated Afloat Networks and Enterprise Services (CANES), the selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Assess briefing spaces, shipboard and otherwise, to identify the current state of the mission planning environment and mission planning processes. Consider communication with mission planners to determine which technological tools would be most utilized in a mission planning environment should also be considered. During Phase I Option, if exercised, perform user interviews that the Government will facilitate and support. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a hardware solution prototype to resolve security considerations and further develop the data reduction solution. Conduct continuous user evaluations facilitated and supported by the Government. Compile user feedback. Further refine the solution regularly. Perform software integration (React | Redux) and testing with NGNMPS. Continuous user evaluations and feedback will be conducted throughout Phase II. Government will facilitate and support user evaluations for performers. Final delivery should include a collaborative workspace that can provide efficient data management (i.e., multiple locations of data entry transmit to one central mission planning hub) and visualization for mission planning using the NGNMPS. Participate in the Scaled Agile Framework (SAFe) process for NGNMPS throughout this phase.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Integrate the software tool into NGNMPS. Conduct security validation and final user evaluations.

The ability to efficiently plan a mission is applicable to other efforts such as fighting wildfires or medical system coordination during a global pandemic. Multiple firefighting agencies must coordinate personnel, assets, and map data during crisis situations. For medical system coordination, similar information must be coordinated within and across hospitals, insurance agencies, and Government. Data visualization that facilitates quick information processing from users will facilitate decision making and quick deployment

of solutions. This rapid information presentation and processing capability can improve decision making timeliness across sectors such as sports, medicine, and emergency response.

REFERENCES:

1. Forlines, C.; Wigdor, D.; Shen, C. and Balakrishnan, R. "Direct-touch vs. mouse input for tabletop displays." Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, April 2007, pp. 647-656. <https://www.merl.com/publications/docs/TR2007-053.pdf>
2. Henderson, J.M. "Human gaze control during real-world scene perception." Trends in cognitive sciences, 7(11), 2003, pp. 498-504. http://jhenderson.org/vclab/PDF_Pubs/Henderson_TICS_2003.pdf
3. Romero, D.; Bernus, P.; Noran, O.; Stahre, J. and Fast-Berglund, A. "The operator 4.0: human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems." IFIP international conference on advances in production management systems, September 016, pp. 677-686. <https://hal.inria.fr/hal-01615707/document>
4. Neisser, U. "Cognitive Psychology: Classic Edition." Psychology Press, 2014. <https://www.biblio.com/book/cognitive-psychology-psychology-press-routledge-classic/d/1332828530?>
5. Seyed, T.; Burns, C.; Costa Sousa, M. and Maurer, F. "From small screens to big displays: understanding interaction in multi-display environments." Proceedings of the companion publication of the 2013 International Conference on Intelligent User Interfaces Companion, March 2013, pp. 33-36. <http://aseold.cpsc.ucalgary.ca/uploads/Publications/2013/p33-seyed.pdf>

KEYWORDS: Mission planning; data management; cybersecurity; automation; networking; Consolidated Afloat Networks and Enterprise Services; CANES

N211-024 TITLE: Munitions Lifting Assembly Sunshade Cover

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials / Processes; Weapons

OBJECTIVE: Develop a strong, lightweight, lowest price, technically acceptable sunshade capable of blocking 70% of solar radiation and attain Naval Ordnance Safety and Security Activity (NOSSA) authorization for use with the A/E32K-11 Munitions Lifting Assembly (MLA).

DESCRIPTION: The United States Marine Corps (USMC) requires the assembly of munitions in forward operational areas. The following descriptions are detailed in two parts: description of the fielded MLA system followed by the required performance of the Sunshade Cover. The solution desired through this effort is for the Sunshade Cover, but details of the MLA are necessary for developing the solution.

In an effort to satisfy the USMC requirements, the Naval Air Systems Command (NAVAIR) procured the A/E32K-11 MLA; a replacement to the legacy A/E32K-3 Munitions Assembly Conveyor, and similar to the A/E32K-9 Munitions Assembly Conveyor II used by the United States Air Force [Ref 1]. The MLA provides a mobile capability for rapid assembly/disassembly of conventional munitions and a means to load/unload them from/onto munitions trailers. The system can be assembled/disassembled in a day, can be packed into three storage containers, and is C-130 transportable, making it capable of expeditionary missions. The system consists of roller conveyors, two A-frame gantries (each with a pneumatic hoist), four rail conveyors with associated munitions cradles, an Interface Control Board (ICB), and a lighting system. The rail conveyors each measure 10 ft (3 m) in length and are assembled end to end to create a 40 ft (12 m) munition assembly line. The two gantries are positioned at either end of the rail conveyor assembly for lifting bulk munitions from incoming pallets and removing assembled munitions from the rail conveyor to a munitions transport vehicle/trailer. The MLA also incorporates a grounding system comprised of a ground rod conforming to (CID) A-A-55804, Type III, Class B; and ground straps connecting the conveyors, gantries, ICB, etc. [Ref 3].

The MLA requires a durable Sunshade Cover approved for use on the system by NOSSA – the technical authority pertaining to ordnance safety and the NAVSEA OP 5 Ammunition and Explosives Safety Ashore [Ref 5]. Design requirements include, but are not limited to, use of a static dissipative (surface resistivity between $10^5 \Omega/\text{sq}$ and $<10^9 \Omega/\text{sq}$) or conductive (surface resistivity $<10^5 \Omega/\text{sq}$) material capable of discharging to ground. The static dissipative properties of the material used should not be met by use of topically applied treatment; that is, sprayed on the material. The material's static dissipative properties must remain stable with long-term UV exposure and under varying humidity conditions. If the Sunshade Cover consists of multiple layers, the layers must be electrically integrated such that the surface resistivity measured with one probe on the outside of the material, and the second on the inside of the material, will yield the same results as if both were on the outside of the material. The Sunshade Cover design must not allow point-discharging and/or must bleed off any accumulated charges in a manner that will reduce the buildup of sufficient charge for electrostatic spark discharge (ESD).

The MLA Sunshade Cover must span the width of the two gantries, about 33 ft (10 m), and provide adequate protection from the sun to operators working in the rail conveyor area. The Sunshade Cover must not hinder the MLA system's stability or operational capability, including the operator's ability to assemble munitions without Sunshade Cover interference. The Sunshade Cover can, but is not required to, be attached to the MLA and must be capable of easy deployment/storage while the MLA structure remains standing about 16 ft in height (5 m). The Sunshade Cover should block at least 70% of solar radiation and be able to withstand the following environmental conditions:

- (a) low Temperature Operating Life (LTOL) with temperatures of -25 °F (-32 °C);
- (b) low temperature storage with temperatures of -65 °F (-54 °C);
- (c) high Temperature Operating Life (HTOP) with temperatures of 140 °F (60 °C) with a solar load;
- (d) high temperature storage with temperatures of 180 °F (82 °C);
- (e) 3% to 95% Relative Humidity (RH) (Ref 2);
- (f) rain, and/or blowing rain, falling at a rate of 2 in./h (5 cm/h) in winds of 40 mph (64 km/h);
- (g) blowing dust in concentrations of 0.3 g/ft³ +/- 0.2 g/ft³ in winds of 35 mph (56 km/h); blowing sand in concentrations of 0.0623 g/ft³ +/- 0.015 g/ft³ in winds of 35 mph (56 km/h);
- (h) ice, freezing rain, and/or water delivery with a rate of 25 mm/h with a droplet size of 1.0 mm–1.5 mm; and
- (i) salt fog for at least 96 hours [Ref 4].

The components comprising the MLA sunshade system should have a minimal footprint when not in use to enable storage in the MLA systems existing storage containers or a small standalone storage container. Material should be shown to resist fungus growth or deterioration. The Sunshade Cover must be field repairable to the greatest extent possible. Periodic maintenance and testing requirements must be minimal to none.

PHASE I: Develop a design for a sunshade cover. Demonstrate the feasibility of the proposed concept in meeting the requirements through analysis and lab demonstrations. Provide one or multiple conceptual designs of an A/E32K-11 MLA Sunshade Cover. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Design and develop a prototype sunshade cover for the A/E32K-11 MLA. Demonstrate use and wear over time to determine any degradation. Provide an estimate of per-unit cost with backup cost data, including parts/manufacturing. Provide a top-level failure analysis and service life estimate. Demonstrate the static dissipative or conductive nature of material using best industry practices. Facilitate and receive NOSSA approval for use of prototype with A/E32K-11 MLA system. Demonstrate that the use of the prototype does not negatively impact use of the A/E32K-11 MLA system. Provide a top-level assessment of whether the cover would pass requirements detailed in Reference 3, and when tested in accordance with the following information: (a) HTOL in 505.7 solar radiation with (procedure) I (cycling and heating effects) of 140 °F (60 °C) ambient air, (b) high temperature storage in 501.7 solar radiation with (procedure) I (storage) of 180 °F (82 °C) maximum; (c) LTOL in 502.7 solar radiation with (procedure) II (operational) in -25 °F (-32 °C) minimum; (d) low temperature (storage) in 502.7 solar radiation with (procedure) I (storage) in -65 °F (-54 °C) minimum; (e) rain in 506.6 solar radiation with (procedure) I (rain and blowing rain); (f) icing/freezing rain in 521.4 solar radiation with (procedure) I glazed ice of 13 mm thick; (g) humidity in 507.6 solar radiation; (h) sand and dust in 510.7 solar radiation with (procedure) I (blowing dust) and (procedure) II (blowing sand) in Air Velocity of 35 mph (56 km/h); and (i) salt fog for 96 Hours [Ref 4].

PHASE III DUAL USE APPLICATIONS: Transition the MLA sunshade for use on the A/E32K-11 MLA. Support United States Government testing and fielding of developed solution. The technology could be used for improved solar protection and material coverage in dusty/explosive environments (e.g., mining, refineries, oil rigs).

REFERENCES:

1. Rowe, C. "MEOC and AAMOC students assemble munitions lifting assembly during WTI 2-18. DVIDS." Defense Visual Information Distribution Service, March 14, 2018.
<https://www.dvidshub.net/image/4236612/meoc-and-aamoc-students-assemble-munitions-lifting-assembly-during-wti-2-18>

2. "MIL-STD-810H, Department of Defense test method standard: environmental engineering considerations and laboratory tests." Department of Defense, January 31, 2019.
http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL_STD_810H_55998/
3. "Commercial item description (CID) rods, ground (with attachments) A-A-55804, (Type III, Class B.)" Defense Logistics Agency, Defense Supply Center Richmond, May 30, 2002.
http://everyspec.com/COMML_ITEM_DESC/A-A-55000_A-A-55999/A-A-55804A_42558/
4. "ASTM B117-19 Standard Practice for Operating Salt Spray (Fog) Apparatus." ASTM International, 2019. <https://doi.org/10.1520/B0117-19>
5. NAVSEA OP 5 VOLUME 3. AMMUNITION AND EXPLOSIVES SAFETY ASHORE FOR CONTINGENCIES, COMBAT OPERATIONS, MILITARY OPERATIONS OTHER THAN WAR, AND ASSOCIATED TRAINING.

Additional information: Request can be made to Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division Detachment Picatinny, G13 Naval PHST Division Bldg. 458, Whittemore Ave. Picatinny Arsenal, NJ 07806-5000: POC: Martin F. Orozco, ihdiv.estm@navy.mil, 973-724-5925 OR Explosives Safety Technical Manuals (ESTM) data is also available on the secure Naval Ordnance Safety and Security Activity (NOSSA) website at:
<https://nossa.dc3n.navy.mil/nrws3/Home.aspx>. You must register for access to the website in order to view the electronic library.

KEYWORDS: Support Equipment; Ordnance; System Safety; Armament; Electrostatic Dissipation; Materials

N211-025

TITLE: Manned-Unmanned Air Vehicle Team Tactical Cloud Analysis

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments; Information Systems

OBJECTIVE: Develop an innovative analysis process to assess/grade various communications technology improvements against operational mission effect chains and outcomes.

DESCRIPTION: The communications complexities in today's battlespace continue to increase at an exponential rate. The Joint force is anticipating and entering an era where our tactical and operational communications dominance is in question and considers the peer/near-peer environment where the potential enemy can interrupt and impede our military operations. Looking to 2030, analysts and military professionals can no longer assume an unfettered technological advantage in the battlefield or established Joint Operational Area (JOA). Given these assumptions, the services have embarked on a variety of advance solutions needed to achieve success in the communications battlefield today's, near-term, and future operating environments. The central theme to future improvements is a force that leverages several key concepts such as agile communications, single source networking, app services, and ultimately, a seamless Joint All Domain Command and Control Combat Cloud.

Crucial in meeting the Joint forces demands of the future is gaining an understanding of the trade space; specifically, looking at the various products and concepts over the intervening years that are intended to help inform and guide service programmatic decision makers to the 2030 timeframe. Numerous developmental efforts such as agile communications, software defined radios, mobile Ad hoc networking, and emerging free space optical communications (FSOC) represent new innovation and in some cases center on refinements of existing capability.

Given the wide array of new innovation, an assessment process is needed in which to ascertain the trade space to overall risk, and with the ability to attain needed capabilities in which to engage and win in all warfighting domains. Typical individual communications research products tend to focus on a given set of metrics such as latency, jitter, link closures, bandwidth usage, and other detailed performance metrics. While detailed measure of performance (MOP) research and analysis is important, there is a significant gap presented to the decision maker, this gap centers on the ability to understand exactly what the trade space is with regard to attaining a desired operational mission F2T2EA (Find, Fix, Track, Target, Engage and Assess) effect, or the ability of a system, or system-of-systems, to successfully execute mission effects chains. The operational mission analysis effects chain analysis would serve to further the overall development of emerging capabilities such as:

- (a) Manned-Unmanned Directional Mesh Enhanced Tactical Airborne Networks. This capability would support missions such as battlespace awareness, target development, intelligence preparation of battlefield, assault support approach and retirement lanes, landing zone evaluation, flank and rear area security, and Tactical Recovery of Aircraft and Personnel (TRAP). The application of the operational mission effects analysis would provide the ability to assess the effects of the Directional Mesh Enhanced Tactical Airborne Networks in quantifiable metrics which would include overall mission accomplishment assessments, risks and the ability to compress engagement–recovery timelines; and
- (b) Analysis of communications and networking solutions in support of Agile Communications architectures focusing on the secure cloud computing environment and impacts to warfare execution based on transactional information flow to and from permissive, contested, and anti-access and area denial (A2/AD) environments.

It is not enough to simply store raw data within the Tactical Combat Cloud-based infrastructure, such as the Hadoop Distributed File System (HDFS) or Apache Accumulo, because this does not provide a

common data model that can be shared across a Multi-Domain Secure Lake architecture that meets the Data Sharing Authoritative Guidance for Enterprise Knowledge Base.

An alternative is a data management strategy and a work flow that recognizes the strengths of the focal plane gate arrays (FPGA)s at the edge with the task of providing specific data to the Tactical Combat Cloud. In turn, the Tactical Combat Cloud recognizes the role of the FPGA and graphics processor unit (GPU) at the edge in a Parent Child relationship. As a child of the cloud, a sensor will respond to tasking low level tasking in support of the overall data objective. The sensor will collect both the locally required (tactical) data as well as the data needed to complete the overall picture of the Tactical Combat Cloud object. The aggregate of sensors via a data normalization strategy will provide the machine to machine analytic to provide the human with a machine enabled decision.

The intent of conducting operation analysis is to provide quantitative data to the various proposed communications and networking solutions as presented. The results are focused on the operational effectiveness and benefit to the warfighter, to include tactical, operational and strategic level of warfare planning and execution. The analysis will aid in identifying:

- (a) the relevance and outcomes of proposed capabilities needed to enable modernization in the near-term and future timeframes when differing information sources, in both content and format are in use and differing information consumers across contexts to which information ought to be transmitted;
- (b) an operational assessment of communications and networking system shortfalls (gaps) such as missing, unreliable, and stale data; and multiple diverse input data/video streams use;
- (c) impacts of current, near-term, and future capabilities versus advancing threat capabilities;
- (d) a rapid and repeatable process that measures the operational impact of various proposed communications and networking solutions in geospatial and temporal relationships that are not permanent;
- (e) a probabilistic interpretation of the unlimited range of actual specific outputs of sensors and analytics to produce meaningful information management decisions and judgements; and
- (f) quality of Service (QoS)

- Frequency of information updates: the rate at which updated values are sent or received.
- Priority of data delivery: the priority used by the underlying transport to deliver the data.
- Reliability of data delivery: whether missed deliveries will be retried.
- Parameters for filtering by data receivers: to determine which data values are accepted and which are rejected.
- Duration of data validity: the specification of an expiration time for data to avoid delivering “stale” data.
- Depth of the ‘history’ included in updates: how many prior updates will be available at any time, e.g., ‘only the most recent update,’ ‘the last n updates,’ or ‘all prior updates’.

Assumptions:

- (a) an IP-routable network is assumed to exist, and be self-managing and self-healing;
- (b) when and where one exists, the local Tactical Operations Center/Forward Operating Base (TOC/FOB) is assumed to be linked to the Global Information Grid/Joint Information Environment (GIG/JIE) with reliable, high-bandwidth connections. Further, it is assumed to have sufficient compute capacity to operate as a local Cloud, offering services to the tactical edge networks (TENs) linked to it;
- (c) operational units are hosting the tactical network within which that warfighter operates. It is further assumed that this tactical network may have attached sensors producing data that would typically be forwarded to the TOC/FOB for data enrichment. If, however, the tactical unit is temporarily disconnected from the TOC/FOB, then it is assumed that there is a local tactical processing gateway (TGW) serving the tactical unit that will offer backup services (appropriate for the compute platform available on the gateway), minimally, performing sensor data enrichment (such as tagging it with the current "team" and "mission") in support of VoI analysis (see below). Note, however, that the proposed architecture allows for a fully distributed gateway meaning that any participating node within the TEN could potentially

“become” the TGW if required due to failure or destruction (albeit with potentially more constrained performance); and

(d) processing power at the tactical node level (individual warfighter) will be extremely limited, due to Size, Weight, and Power (SWaP) rations. Management of the tactical data flow will be managed by one or more TGW nodes at the unit level that can support the additional processing load, such as a vehicle, which connects the TEN to the TOC/FOB network.

PHASE I: Develop an initial concept design to assess/grade various communications technology improvements against operational mission effect chains and outcomes to include requirements analysis and scenario development. Demonstrate that the proposed concept(s) is/are able to provide data distribution and information sharing within a battlespace, where each authorized user, platform, or node transparently contributes and received essential information and is able to utilize it across the full range of military operations among ad hoc and mesh networks. If the Phase I Option is exercised and if appropriate, include data ingress/egress and transformation/subscription services to validate processes, verify processes functionality, and assess processes readiness to conduct trade space analysis versus mission outcomes. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype based on the Phase I design; and demonstrate in a realistic data-to-decision mesh network tactical cloud environment. Propose, test and validate mitigations for any technical issues that are discovered during the testing and assessment. In the first Phase II Option, if exercised, augment in response to events/attacks with a proof-of-concept featuring automation of processes. In the second Phase II option, if exercised, fabricate the prototype using these automated processes and an aggregate of data consistent with these use cases, reflecting system operation over a sufficient period of time on which proposed learning processes can operate. The prototype system should be capable of running level 1 (data resolution) and level 2 (interference) fusion algorithms across geographically separate cloud nodes, each holding different data sources, some streaming; and be able to maintain data models and inferences about behavior while allowing machine learning from a distributed cloud architecture.

PHASE III DUAL USE APPLICATIONS: Assess the prototype performance as part of a technology readiness level 6 or higher demonstration to support transition. Prototype should be capable of producing an application or set of applications that are capable of being generalized to N number of cloud nodes with relevance to Navy and Marine Corps use cases. The Phase III product(s) should be capable of running on program of record cloud systems such as DCGS-N using existing services to run against operational data. Realize the objective should be a concentration of operational relevance and transition. Propose commercial variants of the aerial layer network cloud philosophy.

The use of cloud architectures is becoming prevalent in both the DoD and private sector. Law enforcement and news services are private sectors that have a need to move beyond capabilities that enable data discovery in distributed clouds to systems that can implement complex data fusion algorithms. Data stored in clouds are already being used by these sectors to assess trends and discover events and activities of interest.

REFERENCES:

1. Tu, X. “Management of dynamic airborne network using cloud computing [Conference Session].” 2012 IEEE/AIAA 31st Digital Avionics Systems Conference (DASC), Williamsburg, VA, United States, October 14-18, 2012. <https://doi.org/10.1109/DASC.2012.6383025>
2. Law, E. “Cloud computing @ JPL science data systems. [Conference session].” Ground System Architectures Workshop (GSAW) 2011 Cloud Computing Workshop. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States, March 2, 2011. https://gsaw.org/wp-content/uploads/2013/07/2011s12f_law.pdf

3. Marks, E.A. and Lozano, B. "Executive's guide to cloud computing." Wiley, May 2010. ISBN: 978-0-470-52172-4. <https://dl.acm.org/doi/10.5555/1859444>
4. "D Cloud Way Forward." http://iase.disa.mil/Documents/dodciomemo_w-attachment_cloudwayforwardreport-20141106.pdf (Note: Access to this document requires a CAC.)
5. Dempsey, M.E. "Joint concept for command and control of the joint aerial layer network". Joint Chiefs of Staff, March 20, 2015. https://www.jcs.mil/Portals/36/Documents/Doctrine/concepts/joint_concept_aerial_layer_network.pdf?ver=2017-12-28-162026-103
6. McGirr, S.C. "Building a Single Integrated Picture Over Networks [Paper presentation]." MSS National Symposium on Sensor and Data Fusion, McLean, VA, June 6-8, 2006. <https://mssconferences.org/public/meetings/meetinglist.aspx> (Note: Access requires account set up.)
7. D'Andrea, E.; Ducange, P.; Lazzarini, B. and Marcelloni, F. "Real-Time Detection of Traffic from Twitter Stream Analysis." IEEE Transactions on Intelligent Transportation Systems, 16(4), August 2015, pp. 2269-2283. <https://doi.org/10.1109/TITS.2015.2404431>

KEYWORDS: Cloud; networks; security; Size Weight and Power; SWaP; analysis; Find, Fix, Track, Target, Engage and Assess; F2T2EA; Multi-Domain Secure Lake

N211-026

TITLE: Boron-Based Energetics

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Materials / Processes; Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Determine a form of boron or a boron-based chemical pathway that leads to implementation of boron in energetic compounds, especially fuels (solid and liquid).

DESCRIPTION: Boron combustion tends to form species that are energetic dead-ends (the principal offender in this tendency is H-O-B-O). The use of a small amount of fluorine will tend to interrupt this result by breaking down the ceramic micro-encapsulation that molten boron exhibits. Current work to use boron in solid motors employs this technique, but the results depend on the application and test configuration. One potential reason for this is that this technique uses metallic (bulk) boron as a fuel, with the thermodynamic necessity of melting and evaporating the fuel prior to combustion.

Previous energetics work with boron indicated a necessity to incorporate the boron into potentially unstable compounds, the process of which increased the cost of the feedstock, and raised the likelihood of creating hazardous scenarios in the employment of the compound. Recent developments in the formation of boron allotropes have the potential to both lower feedstock cost and eliminate the need to use hazardous boron-bearing compounds.

A possible alternate combustion pathway begins with another form of boron, either as a compound that yields boron during combustion of another fuel, or an allotrope of boron that features an oxidizing element already attached to it in the desired ratio. Ideally, the attachment of oxidizing species to a boron allotrope would also yield the desired properties that would allow the compound to be successfully employed in a solid motor grain or in a petrochemical liquid suspension or solution.

This topic seeks to survey boron compounds and combustion pathways that enable complete boron combustion (to B₂O₃ or other oxidized species) in both solid fuel and liquid fuel uses. Solutions can be considered in both solid and liquid forms. Compound characterization will be completed using:

- a. Liquid chromatograph-mass spectrometer (LCMS) to identify chemical species;
- b. Gas chromatograph-mass spectrometer (GCMS) to identify chemical species;
- c. Calorimetry to gauge the energetic potential;
- d. Nuclear magnetic resonance (NMR) to characterize atomic arrangement of fuel species;
- e. Fourier Transform Infrared (FTIR) to characterize the evolved combustion species;
- f. Laser ablation of a solid casting to characterize the evolved combustion species;
- g. Combustors set to detect increased in thrust over neat-fuel combustion.

Tailoring the properties of the proposed materials will be undertaken after the determination of the material properties is made and an understanding of the needed property amendments can be described. When a suitable compound is achieved, the material will be tested in both solid and liquid forms. Laser

ablation of a solid casting to characterize the evolved combustion species (captured as gases that are analyzed via GCMS) as well as calorimetry will provide the necessary data to evaluate the proposed use in a solid motor grain. Liquid combustion will be similarly sampled, using a calorimeter, a small-scale afterburner, and in a research-scale RDE. The combustors will provide the combustion gases to be analyzed by GCMS. Additionally, the combustors will be set to detect increases in thrust over neat-fuel combustion.

Work produced in Phase II may be classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA), formerly the Defense Security Service (DSS). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Survey boron compounds and combustion pathways that enable complete boron combustion (to B₂O₃ or other oxidized species) in both solid fuel and liquid fuel uses. Select the most promising compounds and pathways for further development in Phase II. Determine the technical feasibility of boron or a boron-based chemical pathway that leads to implementation of boron in energetic materials in a solid matrix (such as HTPB, or PBAN) for use in solid rocket motors, and in a hydrocarbon fuel (such as JP-10). Consideration of the materials for use in an afterburner or rotating detonation engine while also ensuring material characterization by Fourier-transform infrared (FTIR) and nuclear magnetic resonance (NMR) to ensure full understanding of the material composition. Additional material characterization should include calorimetry to discover the energetic potential of the material, liquid chromatograph mass spectrometer (LMCS) to characterize the compound properties in a liquid or suspended state, and gas chromatograph mass spectrometer (GCMS) to characterize the compound properties in a gaseous state (pre-combusted or combusted). These characterizations should result in understanding the boron-compound's composition, structure, bond energies, energy-release potential, reaction pathways, combustion precursors, and combustion products.

If exercised, the Phase I Option will include tailoring the properties of the proposed materials so that they can be eventually tested in both solid and liquid forms. As new materials, there are no relevant MILSPECs pertaining to their performance testing; however, the materials will fall under the energetic materials testing SOP requirements at NAWCWD China Lake.

PHASE II: Based on Phase I work, continue to develop and validate selected material by modeling of the combustion of the materials to provide predictive results for small-scale testing to be scaled up for larger combustors/larger solid motor grains, while identifying and testing cost-reduction techniques for feedstock and compound production. Successful test results in full scale representative hardware will be documented, as appropriate, and will lead to Phase III.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: A flying demonstrator will summarize progress to date and will collect data that will be of interest to mission requirements generators and technology stakeholders. An inexpensive flight platform will be selected for testing, a flight test will be executed, and the resulting data will be documented. Insertion of the technology into a Program of Record will be sought within PEO

U&W. Production of the materials and techniques to obtain them will be pushed to full-scale, to allow economic production of the needed precursors, and finished fuels.

This technology has the potential to create commercial opportunity in supersonic and hypersonic transport, as well as for the space-launch industry.

REFERENCES:

1. Lee, M. W., Jr. (2016, December 02). Catalyst-free polyhydroboration of dodecaborate yields highly photoluminescent ionic polyarylated clusters. *Angewandte Chemie*, 56(1), 138-142. <https://doi.org/10.1002/anie.201608249>
2. Lee, M. W., Farha, O. K., Hawthorne, M. F., & Hansch, C. H. (2007, April 12). Alkoxy derivatives of dodecaborate: discrete nanomolecular ions with tunable pseudometallic properties. *Angewandte Chemie*, 46(17), 3018-3022. <https://doi.org/10.1002/anie.200605126>
3. Goswami, L. N., Chakravarty, S., Lee, M. W., Jalisatgi, S. S., & Hawthorne, M. F. (2011, April 8). Extensions of the icosahedral closo structure by using azide-alkyne click reactions. *Angewandte Chemie*, 50(20), 4689-4691. <https://doi.org/10.1002/anie.201101066>

KEYWORDS: boron; energetic; rocket fuel; turbine engine; afterburner; material characterization

N211-027 TITLE: Ultra-Lightweight Protection Shielding Material Against Electromagnetic Interference/Electromagnetic Pulse for Avionics

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop an ultra-lightweight carbon-based nanostructure composite shielding material capable of replacing metal shielding for naval electronic and avionics equipment for counter electromagnetic interference/electromagnetic pulse (EMI/EMP) defense.

DESCRIPTION: Recently, various functional nanocomposites are emerging as a new class of EMI/EMP shielding materials with light weight and high functionality. For instance, polymer matrices embedded with carbon-based conductive materials have been demonstrated to attain excellent shielding performance.

It is the objective of this program to develop an ultra-lightweight EMI/EMP shielding material, based on the most state-of-the-art graphene composite, that will form a protective shield for naval avionics and other electronic systems against EMI/EMP threats. The graphene composite should be integrated with lightweight polymer to form conformal shield material that can conform to any shapes and sizes of packaging. The conformal composite should have shielding effectiveness of more than 70 dB across the wide frequency range from 500 MHz to 100 GHz for the completely shielded sensitive electronics/avionics. The electrical conductivity of the graphene composite should be higher than 3000S/cm. The weight of the graphene-based shielding composite should weigh no more than 10% of an aluminum shield with equivalent EM shielding performance.

PHASE I: Develop a shielding material composite and fabrication method that meets shielding protection requirements. Use the proposed fabrication method to fabricate a sample of no smaller than 6 x 6 inches in size with appropriate thickness that will meet the shielding protection requirements. Demonstrate the feasibility of the material design via experimentally characterizing the electromagnetic performance of the sample relative to the metal analog in terms of shielding effectiveness over the frequency range from 500 MHz to 100 GHz, in accordance with the MIL-STD requirements [Refs 5, 6, 7, 8]. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate and validate a three-dimensional (3-D) enclosure prototype for EMI/EMP shielding protection for naval avionics and electronics. The enclosure prototype dimension should be 12x24x6 inches. Perform reliability testing of the prototype enclosure in accordance with MIL-STD 810 [Ref 8] and report the test results. Deliver one prototype for independent testing.

PHASE III DUAL USE APPLICATIONS: Finalize and elevate the EMI/EMP shielding material system. Perform system prototype demonstration in a field environment. Transition the shielding materials to various naval applications such as manned and unmanned air vehicles, radio communication systems, air defense systems, and all avionics and electronics that are vulnerable to EMI/EMP disruptions.

Commercial avionics and electronics can benefit from improved ultra-lightweight shielding of EMI/EMP. Broad and beneficial shielding applications of this type of innovative shielding materials such as any wearable and mobile electronic devices, portable computers, cellular phones, smart watches, and portable/wearable medical devices are envisioned.

REFERENCES:

1. Pereira, V. and Kunkolienkar, G.R. “EMP (Electro-Magnetic Pulse) weapon technology along with EMP shielding & detection methodology [Paper presentation].” Conference Proceedings of the 2013 Fourth International Conference on Computing, Communications and Networking Technologies (ICCCNT), Tiruchengode, India, July 4-6, 2013, pp. 1-5.
<https://doi.org/10.1109/ICCCNT.2013.6726651>
2. Altun, M.; Karteri, I. and Günes, M. “A study on EMI shielding effectiveness of graphene based structures [Paper presentation].” 2017 International Artificial Intelligence and Data Processing Symposium (IDAP 2017), Malatya, Turkey, September 16-17, 2017, pp. 27-31.
<https://doi.org/10.1109/IDAP.2017.8090166>
3. Ismach, A.; Druzgalski, C.; Penwell, S.; Schwartzberg, A.; Zheng, M.; Javey, A.; Bokor, J. and Zhang, Y. “Direct chemical vapor deposition of graphene on dielectric surfaces.” Nano letters, 10(5), 2010, pp. 1542-1548. <https://doi.org/10.1021/nl9037714>
4. Hu, G.; Kang, J.; , Ng, L., Zhu, X.; Howe, R.; Jones, C.G.; Hersam, M.C. and Hasan, T. “Functional inks and printing of two-dimensional materials.” Chemical Society Reviews, 47(9), 2018, pp. 3265-3300. <https://doi.org/10.1039/c8cs00084k>
5. “MIL-STD-461G, Department of Defense interface standard: requirements for the control of electromagnetic interference characteristics of subsystems and equipment.” Department of Defense, December 11, 2015. http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-461G_53571/
6. “MIL-STD-464C, Department of Defense interface standard: electromagnetic environmental effects, requirements for systems.” Department of Defense, December 1, 2010. http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-464C_28312/
7. Reference removed, document no longer available to the public.
8. “MIL-STD-810H, Department of Defense test method standard: environmental engineering considerations and laboratory tests.” Department of Defense, January 31, 2019. http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/

KEYWORDS: Electromagnetic interference; EMI; electromagnetic pulse; EMP; shielding; lightweight composite; graphene; nanocomposite

N211-028

TITLE: Conformal Antennas Miniaturized through Magneto-Dielectric Materials

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Battlespace Environments; Electronics

OBJECTIVE: Demonstrate printed-microstrip antenna size reduction through substrate permeability for improved size, weight, and power (SWaP), bandwidth performance, phased array architecture, improved low observability and probability of detection characteristics.

DESCRIPTION: The limits of microstrip antenna miniaturization are reached as permittivity values approach low double digits; at which point the antenna becomes too inefficient a radiator for practical use in an airborne communication system. Appreciable reductions in microstrip antenna size can be gained through an increase in the permeability of the printed antenna's substrate [Refs 1, 3, 5, 6]. When compared to traditional permittivity (only) increases, a combination of standard permittivity increases with novel permeability increases could result in comparable size reduction and better Radio Frequency (RF) performance [Refs 1, 3, 6]. The permittivity of printed antenna substrates is often increased to decrease antenna size, sacrificing antenna efficiency resulting in poorer RF performance and heat generation [Refs 2, 4, 6]. Permeability can also be increased to reduce size while counterbalancing the effect of permittivity increases on the antenna's characteristic impedance, resulting in a better performing, more efficient, miniaturized antenna that operates over a wider bandwidth [Refs 1, 3, 6]. Smaller conformal printed antennas can be integrated while minimizing impact to the aerodynamic characteristics of the hosting aircraft. Smaller antennas that have undergone a 50% reduction in size due to magnetic properties are sought. In addition, miniaturized conformal antennas can be integrated while minimizing negative impacts to the Radar Cross Section of an aircraft, when compared to common antennas. Aircraft with smaller conformal antennas operating from the Aircraft Carrier (Nuclear Propulsion) (CVN) could potentially have better Low Observable/Low Probability of Detection (LO/LPD) profiles than their standard counterparts, decreasing the likelihood of CVN detection.

PHASE I: Develop an initial conceptual design for a conformal microstrip patch antenna that has been reduced in size by 50% solely as a result of the substrate material's electromagnetic permeability characteristics while minimizing loss so that loss is comparable with practical printed antennas miniaturized through other means. Perform modeling and simulation in order to provide a conceptual design trade study for the antenna and its substrate. The Phase I Option period, if exercised, must include developing an initial antenna design that includes a plan for substrate fabrication, antenna feed design, and anticipated prototype antenna fabrication cost. Any microstrip antenna shape can be considered, as well as any permittivity characteristic for the substrate as long as a 50% reduction in size due to magnetic properties can be demonstrated. The design must also demonstrate improved antenna efficiency and frequency bandwidth for the prototype antenna over traditional antennas of equivalent size that have been miniaturized solely through increased permittivity. The Phase I effort must design, develop, and deliver a model of the antenna radiation pattern, impedance, efficiency, and explanation of antenna miniaturization attributes. The Phase I effort must include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype based on the Phase I design. Test antenna prototype to validate maturity and expected/modeled performance. Characterize initial prototype's performance, identify any deviations from modeled performance and cause(s) for deviation, and produce improved design to address deviations and deficiencies. The Phase II Option period, if exercised, must produce an improved prototype; it must characterize improved prototype's performance; and identify any deviations from expected performance and cause(s) for deviation.

PHASE III DUAL USE APPLICATIONS: Complete development of the miniaturized antenna, demonstrate performance in an operationally relevant environment. Miniaturized conformal antennas would find use on any commercial aircraft or space vehicle desiring to save weight while achieving the same or better communication system performance experienced with legacy antenna options.

REFERENCES:

1. Hansen, R.C. and Burke, M. "Antennas with magneto-dielectrics." *MicroWave and Optical Technology Letters*, 26(2), July 20, 2020, pp. 75-78. [https://doi.org/10.1002/1098-2760\(20000720\)26:23.0.CO;2-W](https://doi.org/10.1002/1098-2760(20000720)26:23.0.CO;2-W)
2. Niamien, C.; Collardey, S.; Tarot, A.-C. and Mahdjoubi, K. "Revisiting the Q factor of PIFA antennas for dielectric and magnetic media [Paper presentation]." *Proceedings of the 2nd International Congress on Advanced Electromagnetic Materials in Microwave and Optics—Metamaterials 2008*, Pamplona, Spain. https://www.researchgate.net/publication/281804229_Revisiting_the_Q-factor_of_PIFA_antennas_for_dielectric_and_magnetic_media
3. Niamien, C.; Collardey, S. and Mahdjoubi K. "Printed antennas over lossy magneto-dielectric substrates [Paper presentation]." *Proceedings of the Fourth European Conference on Antennas and Propagation (EuCAP)*, Barcelona, Spain, April 12-16, 2010. https://www.researchgate.net/publication/224153919_Printed_antennas_over_lossy_magneto-dielectric_substrates
4. Huang, Y.P. and Zhang, X.Z. "Effect of magneto-dielectric material in different antenna structures [Paper presentation]." *2011 Asia-Pacific Microwave Conference Proceedings (APMC 2011)*, Melbourne, Australia, December 5-8, 2011, pp. 1039-1042. <https://ieeexplore.ieee.org/document/6173932>
5. Riaux, D.; Sharaiha, A.; Tarot, A.-C. and Delaveaud, C. "Estimation of the effective medium for planar microstrip antennas on a dielectric and magnetic truncated substrate." *IEEE Antennas and Wireless Propagation Letters*, 11, November 20, 2012, pp. 1410-1413. <https://doi.org/10.1109/LAWP.2012.2229100>

KEYWORDS: antenna; conformal; magneto-dielectric; miniaturized; permeability; permittivity

N211-029 TITLE: Recovery and Handling of Group 3 through Group 5 Unmanned Aerial Vehicles Aboard Navy's Expeditionary Sea Base

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Recovery and Handling of Group 3 through Group 5 fixed wing UAVs from ships other than an aircraft carrier to significantly increase lethality, project force, and increase the coverage of Intelligence, Surveillance and Reconnaissance (ISR) assets.

DESCRIPTION: The USAF's XQ-58A Valkyrie drone aircraft is the primary fixed wing Unmanned Aircraft System (UAS) planned for integration into Navy ships smaller than aircraft carriers. This SBIR topic complements a previous NAVAIR topic N202-109 entitled "Launch System for Group 3-5 Unmanned Aerial Vehicles for Land-and Sea-Based Operations." In order to reduce costs, the XQ-58A was not designed to be outfitted with landing gear. The Air Force instead uses rocket assist to launch the drone and deploys an on board parachute for recovery. The Navy under this topic is seeking an innovative approach that does not mandate the use of a parachute in order to recover the XQ-58A. Additionally, this topic needs to address the recovery of group 3 through 5 UAVSs that are outfitted with their own landing gear and equipped with a tail hook.

Operation of Group 3 through Group 5 (Group 3-5) fixed wing Unmanned Aerial Vehicles (UAVs) from ships other than aircraft carriers with a UAV Capture and Handling System must be capable of decelerating a fixed wing jet-powered UAV, with a wingspan of 30 feet and weight up to 6000 pounds, down from speeds up to 160 Knots Indicated Air Speed (KIAS). The placement of system components must reside, to the maximum extent possible, within the hull of the Expeditionary Sea Base (ESB) class of ships. Coordination with both Naval Sea Systems Command (NAVSEA) and Naval Air Systems Command (NAVAIR) will be critical to understanding the available space(s) aboard ship for system placement to minimize mission impact of other functions of the ship, as well as any weight and power restrictions.

The Recovery and Handling System must be designed to not interfere with normal topside flight deck operations of the ESB and accommodate Group 3-5 UAVs with or without landing gear including the Air Force XQ-58A Valkyrie. It must also be reconfigurable such that it can be transported to conduct both ground-based operations and shipboard operations aboard an ESB. Should features of the system exceed available onboard space, a stowable sponson assembly can be envisioned to extend from either side of the ESB, serving as the UAV "runway" and interfacing directly with the capture and handling technology. The sponson may extend as far as 79 feet from the ESB and is limited to a length of 300 feet. Any design solution relying on a sponson must address impact on the ship's performance, both pier-side and at sea, and may not interfere with basic ship or flight deck operations. Ship attitude during UAV recovery should be at a fixed bearing to optimize wind conditions and ship speed up to 15 knots as required.

The UAV Recovery and Handling System must be simple enough in design to allow for sustained operations at high sortie generation rates with a goal of a UAV capture every two minutes. The system must demonstrate high reliability with minimal maintenance down time for 24 hour/7 day surge periods. It is desired that routine maintenance should be accomplished in stride with operations. Details of the Recovery and Handling System need to include all the necessary subsystems and interface components required for installation aboard the ESB. The system must also adhere to all applicable environmental standards of the latest version of MIL-STD-810 such as shock, vibration, electromagnetic interference/emission, etc.

PHASE I: Develop a concept design to meet the objectives in the Description. Through modeling and simulation, demonstrate the feasibility of the concept in meeting Navy needs and establish that the concept can be developed into a useful product for the Navy. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop and deliver a prototype. Demonstrate a 1/8 scale prototype of the Launch System using a 100-pound UAV provided by the Government, conduct a ground demonstration of the prototype Recovery and Handling System. If the land-based testing is determined to be successful, a full-scale design suitable for at-sea testing will be developed during the options of the Phase II effort. This prototype development will involve multiple ship check visits to an ESB Class ship on either the east or west coast of the United States. One full-scale prototype will be constructed for both the land-based and at-sea testing. After successful full-scale land based testing, at-sea testing will follow in further development.

PHASE III DUAL USE APPLICATIONS: The technology being developed in this proposed NAVSEA SBIR topic as well as NAVAIR SBIR N202-109 are being planned for installation aboard a ESB to enable operation of fixed wing UAVs with or without landing gear ranging in size from Group 3 through 5. In addition to being able to operate these fixed wing UAVs from ships the Marine Corps have expressed interest in having this same technology packaged in kit form, so it could be transported via ground vehicles in the field to remote areas including islands and readily assembled by troops operating in the field to enhance air domination as the USMC seek to engage our enemies in their own backyard. This type of technology could be useful for commercial UAV delivery systems in cities.

The growing industry of aerial consumer package delivery could be profoundly impacted by advances in UAV capabilities.

REFERENCES:

1. Shugart T. Commander, "Build all-UAV Carriers", USNI Proceedings Vol. 143/9/1,375 (September 2017). <https://www.usni.org/magazines/proceedings/2017/september/build-all-uav-carriers>
2. Defense Industry Daily, "EMALS/ AAG: Electro-Magnetic Launch & Recovery for Carriers", March 2019. <https://www.defenseindustrydaily.com/emals-electro-magnetic-launch-for-carriers-05220/>
3. Penn State Department of Geography, College of Earth and Mineral Sciences, "Classification of the Unmanned Aerial Systems", <https://www.e-education.psu.edu/geog892/node/5>
4. MIL-STD-810H, DEPARTMENT OF DEFENSE TEST METHOD STANDARD: ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS (31-JAN-2019) http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/

KEYWORDS: Unmanned Aerial Vehicle (UAV); Unmanned Aircraft Systems (UAS); Expeditionary Sea Base (ESB); XQ-58A Valkyrie; Sponson; Group 3 through Group 5 UAV.

N211-030 TITLE: Kilowatt (kW) Class Continuous Wave (CW) and Pulse Laser Hardened Optical Systems for Submarines

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a Kilowatt (kW) class Continuous Wave (CW) and Pulse laser hardened optical system for submarines.

DESCRIPTION: Submarines may be subject to high power laser beams, which may damage optics and sensors in beam directors and periscopes. The Navy is seeking a technology that would allow laser hardening of vulnerable optical components in beam directors, periscopes, or other optical system without compromising their functional capabilities such as imaging, and directing a high-energy laser beam with no losses or wave front distortion. The radiation hardening system will integrate into submarine optical systems to include at minimum beam directors, periscopes, and imaging systems. Commercial optics employ thin films whose primary purpose is not the scope of this SBIR topic.

The Navy is seeking a design to be developed employing technology based on 4th generation transparent materials. In general, the current thin film based technology, thin enough not to generate substantial heating within the film when exposed to the high-power laser beams, while still having high optically nonlinear response to the influence of high power CW (continuous wave) or pulsed laser beams of relevant wavelengths will be considered. Due to 100's kW class CW laser power at 1 or 1.5 μm laser wavelength and picosecond laser pulse of greater than 10 mJ per pulse, the material response shall not be accompanied with increased absorption as for example two-photon absorption per pulsed beams. The blocking of the high-power beams shall rather be a result of beam deflection away from the vulnerable optics into, for example, a radiation dump. Such photo-triggered diffraction gratings should diffract over 99% of radiation and have an aperture up to 12" in size. The proposed materials damage threshold shall be greater than 100's MW for CW and greater than gigawatts for pulse lasers at 1 and 1.5 μm wavelength. Prototypes will be tested at a Navy lab in order to test, evaluate, and validate the specifications identified above.

Passive approaches will be considered, provided they are capable of rejecting high-power beams with an efficiency of rejecting greater than 80% of the optical power with only 20 degrees C of additional increase in the substrate temperature. Thin film photonic bandgaps, passive or photo-responsive seem particularly promising for this purpose.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial

Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Provide a concept to solve the Navy's problem based on the requirements in the Description, and demonstrate the feasibility of that concept. Develop a concept for laser hardening and perform a trade study for submarine applications. Demonstrate feasibility through modeling and simulation. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a prototype system for HEL kW class direct high energy laser testing and evaluation based on the results of Phase I and the Phase II Statement of Work (SOW). Develop the required technology into a prototype device and demonstrate that it meets the requirements in the Description. Test and refine the prototype into a technology that the Navy can use. Deliver the prototype laser hardened optical system, around 12 inch in diameter for kW class test and evaluation by U.S. NAVY.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support transitioning the technology for Navy use. Identify the final prototype product for transition into NAVSEA undersea platform and plan for the transition to Phase III, to include validation, testing, and HEL testing for Navy use. This technology has potential commercial transition to other applications such as industrial material processing window (welding, cutting, soldering, marking, cleaning, etc.) and fundamental research window.

REFERENCES:

1. S.R. Nersisyan, N.V. Tabiryan, D.M. Steeves, B. Kimball, Optical Axis Gratings in Liquid Crystals and their use for Polarization insensitive optical switching, *Journal of Nonlinear Optical Physics & Materials*, 18 (1), 1–47, 2009.
<https://www.worldscientific.com/doi/abs/10.1142/S0218863509004555>
2. S. V. Serak, N.V. Tabiryan, T. J. Bunning, Nonlinear transmission of photosensitive cholesteric liquid crystals due to spectral bandwidth auto-tuning or restoration, *J. Nonlinear Optical Physics & Materials*, 16 (4), 471-483, 2007.
<https://www.worldscientific.com/doi/abs/10.1142/S0218863507003895>
3. N. Tabiryan, D. Roberts, D. Steeves, and B. Kimball, "4G Optics: New Technology Extends Limits to the Extremes," *Photonics Spectra*, March, 2017, pp. 46-50.
https://www.photonics.com/Articles/New_4G_Optics_Technology_Extends_Limits_to_the/a61612
4. N.V. Tabiryan, S.R. Nersisyan, D.M. Steeves and B.R. Kimball, The Promise of Diffractive Waveplates, *Optics and Photonics News*, 21 (3), 41-45, 2010.
<https://www.osapublishing.org/opn/abstract.cfm?uri=opn-21-3-40>

KEYWORDS: Pulse laser; laser hardened optical system; photo-responsive; laser damage threshold; picosecond pulse (ps); nonlinear optics.

N211-031

TITLE: Compact RAMAN System for Marine Wave Boundary Characterization

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an advanced detection and targeting control for High Energy Laser (HEL) operating in the complex marine environments where the proposed RAMAN metrological sensor will also improve the submarine imaging and Radio Frequency (RF) detection.

DESCRIPTION: The Navy seeks technologies that are oriented toward a deeper experimental and theoretical understanding of maritime turbulence and laser light propagation in the marine boundary. Ocean evaporation is occurring within a very thin molecular layer at the surface. However, there are indications that turbulent structures in the ocean and atmospheric mixing layers play a critical role in determining the water vapor flux. The current measurement techniques, such as Laser Doppler Velocimetry (LDV), are limited to resolutions of 1 micro meter or greater and fall short of the required sub micrometer level resolution. A new type of spectral imaging modality and instrumentation is required that will increase our understanding of ocean evaporation and lead to better tools for measuring and modeling the near-marine boundary layer for optical and radio frequency Naval applications. This generalized understanding will significantly enhance beam optic directors, adaptive optics, and other turbulence mitigating techniques to enhance the reach and effectiveness of communication as well as defensive and offensive laser light engagement in the marine boundary layer.

The overall objectives of this STTR topic are to: 1) develop a system capable of measuring atmospheric turbulence near the ocean surface (0 to 60 feet); 2) develop models that can predict turbulent effects given a set of atmospheric and marine surface conditions, such as surface temperature, humidity, pressure, wind speed, wave, fog, etc., that can affect marine wave boundary layer atmosphere; and 3) develop a metrological instrument based on RAMAN light detection and ranging (LIDAR). A RAMAN metrology system should be capable of accepting RAMAN signals from lasers operating in three octaves from the Near-Infrared (NIR) (~1 um), Visible (~500nm), to the Deep Ultraviolet (DUV) (~250nm). The multi-band RAMAN metrology system's simultaneous backscattering analysis of three wavelength intensity measurement ratio would be able to validate atmospheric Rayleigh and Mie scattering models. The system would be used to adapt existing atmospheric models or creating new physics-based models of the marine boundary layer. The RAMAN spectrometer must be able to collect data at a repetition rate of at least 1 kHz in all three wavelength ranges. The metrology system technology should be compatible with a marine operating environment in accordance with MIL-STD-810H and capable of integration into a submarine sail or mast. This form factor capable of fitting within a 12 inch cubed volume would facilitate widespread deployment as a metrological tool for marine wave boundary atmospheric characterization. The RAMAN metrology system (multiband source, detector and software for analysis) is also the part of High Energy Laser (HEL) closed loop circuit to control the HEL beam on target. The proposed 3-band picosecond RAMAN laser shall be able to integrate into HEL systems for target ranging and detection. In this configuration, the system has the potential to enhance substantially Navy capabilities for deployed

high power lasers operating in the marine environment. In this effort the proposer should use Open Model Based Engineering (MBEE) for the development of software, hardware and documents.

Testing and evaluation will occur at a Navy laboratory and will measure the effectiveness of the RAMAN metrology system to accept three synchronized laser pulses in the ultra violet (UV), visible (VIS), and infrared (IR) spectral bands. The laser pulse will have a temporal pulse width between 5 ps and 1 ns and a pulse repetition rate between 1 kHz and 5 kHz, and a stable, narrow laser bandwidth of a few wavenumbers or less sufficient to distinguish RAMAN lines. The RAMAN metrology system (multiband source and detector) should have a resolution of a few wavenumbers in each spectral region. The company shall acquire mJ per pico second multiband source for the compact RAMAN System development. The Government may also furnish a 3-band mJ per band pico source as a second source to the company for integration and comparison studies into compact RAMAN System. Both software and hardware of the integrated RAMAN system (source and detector) are to be delivered to Navy.

PHASE I: Develop a concept for a RAMAN metrology system based on Model Based Engineering (MBE) as outlined in the Description. Demonstrate the feasibility of that concept through architecture modeling, simulation, and theoretical calculation. Ensure that the RAMAN metrology system is capable of producing the required spectral resolution in each of the wavelength bands at the predicted repetition rate. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a RAMAN metrology prototype solution based on MBE.

PHASE II: Develop and deliver a prototype of a 3-band RAMAN metrology system based on the concept developed in Phase I and the Phase II Statement of Work (SOW). Integrate the RAMAN metrology system with the 3-band laser source, detector and software for analysis. Work with the Navy for the evaluation of performance and further characterization for the purpose of RAMAN back scattering to characterize atmospheric temperature, pressure, and humidity. Support the Navy for validation and additional testing to be qualified and certified for Navy use.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy submarine platforms as a metrological tool for marine wave boundary data collection. This technology can improve a commercial ship's localized weather prediction and update the weather software for safe operation. Additionally, improved LIDAR detection for range at day, night, and all-weather conditions is beneficial for both commercial and DoD applications. The RAMAN metrology system could also find applications in trace gas and pollution monitoring.

REFERENCES:

1. Wasiczko Thomas, Linda M., Moore, Christopher I.; Burriss, Harris R.; Suite, Michele; Smith Jr., Walter Reed and Rabinovich, William. "NRL's Research at the Lasercomm Test Facility: Characterization of the Maritime Atmosphere and Initial Results in Analog AM Lasercomm." Proc. SPIE, 6951, Atmospheric Propagation V, 69510S, April 18, 2008.
<https://doi.org/10.1117/12.783791>
2. Whiteman, David N. "Examination of the traditional RAMAN lidar technique. I. Evaluating the temperature-dependent lidar equations." Appl. Opt. 42, 2003, pp. 2571-2592.
<https://doi.org/10.1364/AO.42.002571>
3. Whiteman, David N. "Examination of the traditional RAMAN lidar technique. II. Evaluating the ratios for water vapor and aerosols." Appl. Opt. 42, 2003, pp. 2593-2608.
<https://doi.org/10.1364/AO.42.002593>
4. Deng, Chunhua; Brooks, Sarah D.; Vidaurre, German and Thornton, Daniel C. O. "Using RAMAN Microspectroscopy to Determine Chemical Composition and Mixing State of Airborne Marine Aerosols over the Pacific Ocean." Aerosol Science and Technology, 48:2, 2014, pp. 193-

206. DOI: 10.1080/02786826.2013.867297

<https://www.tandfonline.com/doi/full/10.1080/02786826.2013.867297>

5. "Department of Defense Test Method Standard Environmental Engineering Considerations and Laboratory Tests", Department of Defense, Serial Number MIL-STD-810H w/Change 1, 15 Apr 2014 https://www.navysbir.com/n21_1/N211-031-REFERENCE-5-MIL-STD-810G.pdf

KEYWORDS: RAMAN LIDAR; Laser Beam Propagation; Maritime Environment; Turbulent Boundary Layer; 3-band RAMAN Laser System; Laser Doppler Velocimetry (LDV).

N211-032 TITLE: Extra Large Unmanned Undersea Vehicle (XLUUV) Launch and Recovery, On-Board Handling, and Servicing System

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a modular Launch and Recovery system for On-Board Handling and Servicing of Extra Large Unmanned Undersea Vehicle (XLUUV) that can be used on amphibious platforms.

DESCRIPTION: Current Unmanned Surface Vehicle (USV), Unmanned Undersea Vehicle (UUV) recovery systems are designed for the LCS Classes or Shore based operations, and not easily transferrable to other Ship Classes. The Extra Large Unmanned Undersea Vehicle (XLUUV) with a length of 85 feet, weight of 180,000 pounds and height and width of 8.5 feet would provide a physical challenge to deploy from any Navy ship. These systems are specially designed to capture an Unmanned Vehicle (up to the Large Diameter size) and bring it onboard an LCS using the Twin Boom Extensible Crane (TBEC) on the Independence Class or Launch Recovery Handling System (LRHS) on the Freedom Class. The TBEC and LRHS are specialized systems with unique design features that are not found on other platforms throughout the fleet. Since the original design for the launch & recovery systems were tailored to the LCS variants, they do not integrate easily on other Ship Classes where conventional launch and recovery procedures are used. Current launch and recovery requirements drive the Navy to develop unique solutions that are not cross compatible with other USVs, UUVs, and XLUUVs. The technology to be developed in this effort will provide NAVSEA with a common launch and recovery capability deployed on LCS, L-class, and Shore-based platforms to launch and recover vehicles in the NAVSEA UxV portfolio. The developed launch and recovery system must not require structural modifications to the ship, must operate in Sea State 3 and the design should not impede stern gate actuation, ballasting, or other critical ship operations. A preferred system would be modular, adaptable and scalable to support smaller future unmanned systems.

The LPD 17 Class ships mission is to transport troops and equipment for amphibious operations and land them in the assault area by means of embarked Landing Craft Air Cushion (LCAC), conventional landing craft, or Amphibious Assault Vehicles (AAV). Each LPD 17 Class ship encompasses more than 22,000 square feet of vehicle storage space and 28,000 cubic feet of cargo storage. Vehicle storage space is provided through a well deck design. The LPD 17 Class well deck is 188 feet long and approximately 50 feet wide at mid well, increasing to 59 feet at the sill, or stern of the ship. Clearance above the well deck is 31 feet. The ship is able to ballast down to flood the well deck with 9 feet of seawater at the sill and 4.5 feet at the forward portion of the well during wet well operations and landing craft maneuvers.

PHASE I: Develop a concept for a modular Launch and Recovery system for On-Board Handling and Servicing of the current Navy XLUUV that can be used on an LPD 17 class of ship. The Navy will provide dimension and movement specifications for both the unmanned system, and the ship locations in which the modular Launch and Recovery system for On-Board Handling and Servicing would reside. Companies will demonstrate feasibility of their designs through modelling and draft concepts of operation. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop and deliver a prototype modular Launch and Recovery system for On-Board Handling and Servicing of the Navy XLUUV on the LPD 17 class of ship. This prototype development will involve multiple ship check visits to a LPD 17 Class ship on either the east or west coast of the United States. The prototype will first be evaluated on land at both the company's facility and the location where the XLUUV is stored

to determine the system's capability in meeting the performance goals defined in Phase II SOW. If the land-based testing is determined to be successful, at-sea testing will be accomplished at the end of the Phase II effort with the XLUUV and the company's prototype modular Launch and Recovery system for On-Board Handling and Servicing. The at-sea testing will involve the company's system demonstrating movement of the XLUUV from a stowage location on the vehicle deck to the well deck, and then launching and recovering the XLUUV. One overall prototype can be used for both the land-based and at-sea testing. Validation and qualification of the final company product will be achieved during Phase II. The company will prepare a Phase III development plan to transition the technology to Navy use.

PHASE III DUAL USE APPLICATIONS: Upon successful completion of Phase II, the company will be expected to support the Navy in transitioning the technology to Navy use. The company will refine the design of the final modular launch and recovery system that can be used for the XLUUV, but also adapted to other Navy unmanned systems. The company will support the Navy for test and validation in accordance with Navy regulations and requirements. Following testing and validation the end design is expected to first be deployed on the LPD 17 Class, and capable of being utilized across all Navy amphibious platforms with well decks. This technology will help the Navy meet critical needs of increased warfighting capability for L-Class ships and expand the Amphibious Warfare Mission Area(s).

REFERENCES:

1. O'Rourke, Ronald. "Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress." Congressional Research Service. March 30, 2020.
<https://fas.org/sgp/crs/weapons/R45757.pdf>
2. Mayfield, Mandy. "Navy Seeking New Technology For Unmanned Boats, Subs." National Defense Magazine. October 18, 2019
<https://www.nationaldefensemagazine.org/articles/2019/10/18/navy-seeking-new-technology-for-unmanned-boats-subs>

KEYWORDS: Unmanned Maritime Vehicle Systems; Launch and Recovery; Unmanned Undersea Vehicle (UUV); Extra Large Unmanned Undersea Vehicle (XLUUV); Modular Unmanned System; Unmanned Vehicle Stowage.

N211-033 TITLE: Wireless Sensing to Improve Submarine Machinery Health Monitoring

RT&L FOCUS AREA(S): Networked C3

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a solution that can wirelessly monitor and transmit shipboard machinery data to provide an easy means of collecting data on an operational platform to enhance machinery health monitoring.

DESCRIPTION: The U.S. Navy does not currently employ autonomous continuous based machinery monitoring and predictive maintenance systems aboard fleet platforms – current methods although broadly effective may be infrequent, labor intensive, prone to measurement error and may delay actionable information to decision makers. Current methodologies in the submarine fleet, for example, employ periodic, hand-held, wired machinery vibration measurements to provide predictions of machinery failure.

The Navy is thus seeking a broad range of emerging technologies that take advantage of commercial advances in sensor development, Internet of Things (IoT), and data analytics as applied to machinery data to develop digital twins that allow for Condition Based Maintenance (CBM) of assets. Monitoring the current and expected future states of these systems will allow the Navy to more effectively maintain their platforms through an increased awareness of system health. Furthermore, maintenance planning is better served by an increased awareness of remaining useful life of components. By analyzing the optimal mix of resilient design and onboard/forward deployed spares, this solution supports On Time Delivery by maintaining the right parts where they are most needed to support the mission, ultimately reducing life cycle costs of the program sustainment activities.

Of specific interest, the Navy is interested in the use of wireless sensing technologies that can simultaneously collect and transmit machinery vibration (0 – 6000 Hz) and power data (current and voltage TBD) that are in conformance with naval platform operational restrictions. Although this technology has been demonstrated in academia, there is no commercial application of such technology aboard current Navy platforms.

Use of wireless sensing technologies will provide an easier means of collecting and storing data from a broader range of sensors when compared to similar wired solutions. The small business should develop a combination of software (sensor proprietary if necessary; COTS telemetry infrastructure) and hardware that would allow for collection of data from shipboard machinery and wirelessly transmit this data to an onboard storage or display device.

The solution should allow for a minimum of two simultaneous sensing modalities – mechanical vibration and machinery power attributes – to support monitoring of machinery health. Additional sensing modalities could include temperature, pressure, or acoustics depending on the type of machinery monitored. The developed sensor should be able to obtain power at its installed location source and should not require cabling to a remote power source. Solutions that do not require human intervention, i.e., replacement of batteries, are preferred but not required. The solution could, but is not required to, be applicable to either manned or unmanned platform. However, the solution will be required to communicate data securely from the sensor to the storage medium on board the submarine.

While the solution provided by the company will be used to support the development of digital twins for Condition-Based Maintenance (CBM), CBM solutions are not required to be provided as a deliverable. Rather the vendor should focus on developing a modular infrastructure that allows for secure

communication between the sensor and storage location. These communication protocols will be platform dependent but include considerations such as physical access controls, power management and environmental controls and strategic/local command security protocol procedures. Size, weight and power should be constrained to not interfere with machinery operation and to operate autonomously in excess of two weeks without maintenance (e.g., battery replacement).

The Phase II effort is anticipated to include testing by the small business in an operationally relevant environment with final testing by the Navy (Naval Surface Warfare Center, Carderock Division) in a laboratory or at-sea environment as appropriate. The product will be validated, tested, qualified, and certified for Navy use across a wide range of conditions (e.g., machine operating parameters, ship depth, sea water temperature, etc.) as applicable for the relevant class of problem.

Depending on the scope of the proposal, the Phase II effort may require secure access, and NAVSEA will process the DD254 to support the contractor for personnel and facility certification for secure access. The Phase I effort will not require access to classified information. If need be, data of the same level of complexity as secured data will be provided to support Phase I or Phase II work.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept to solve the Navy's problem and then demonstrate the feasibility of that concept. The expected product will be a combination of hardware and software. Feasibility should be demonstrated by a laboratory bench test or a limited scale field experiment. As an example, a vendor might propose a demonstration of one modality of data being collected on a representative asset in the lab and transmitted securely to a storage device and/or display. The vendor is expected to propose concept feasibility testing as part of their proposals. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype system for testing and evaluation based on the results of Phase I work and the Phase II Statement of Work (SOW). The prototype system will vary based on the awardee's proposed approach, but it may include hardware and software. The test and evaluation hardware may be a commercial system (e.g., a commercially available vent fan), a Navy-provided system (e.g., a main seawater pump), or a combination of commercial and Navy-provided systems (e.g., an integrated life support system). The prototype will be evaluated in a Navy lab or at-sea environment. The Navy may opt to choose a surrogate platform for at-sea testing based on availability of assets. Additional laboratory testing, modeling, or analytical methods may also be appropriate depending on the company's proposed approach. In general, two prototype articles should be provided to the Government for testing, at least three months prior to the end of Phase II. A Phase III development plan will be required at the end of Phase II.

It is probable that the work under this effort and any follow-on efforts could be classified (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. The final product will be software integrated with Navy-provided hardware, or software integrated with company-provided hardware. The Navy expects the vendor to support transition to Phase III through system integration, testing support, software and hardware documentation, and limited hardware production if applicable. Possible platforms where the technology will be used include current and future submarine platforms. The technology must meet critical Navy requirements in terms of secure communications between the source and the storage medium onboard the platform. These may be related to WLAN security (encryption, authentication), Electromagnetic Interference (EM), radiological and hazardous material constraints, limits on total radiated power and other relevant requirements in effect at such time. In Phase III, the product will be validated, tested, qualified, and certified for Navy use in at-sea trials across a wide range of conditions as applicable for the relevant class of problem. Additional software testing will likely also be required to ensure that all applicable conditions can be tested even if they do not occur during at-sea test periods.

These solutions have potential for use on other undersea platforms such as Unmanned Undersea Vehicles (UUVs) as well as a wide range of surface platforms.

REFERENCES:

1. Green, D.; Lindahl, P.; Leeb, S.; Kane, T.; Kidwell, S., Donnal, J., “Dashboard: Nonintrusive Electromechanical Fault Detection and Diagnostics.” Proc. IEEE International Automatic Testing Conference, Aug 2019, 1-7. <https://ieeexplore.ieee.org/document/8961062>
2. Hodge, V.J.; O’Keefe, S.; Weeks, M.; Moulds, A., “Wireless Sensor Networks for Condition Monitoring in the Railway Industry”, IEEE Trans on Intelligent Transportation Systems, Vol. 16, No. 3, 2015, 1088-1106 <https://ieeexplore.ieee.org/document/6963375>
3. Hou, L.; Bergmann, N.W., “Novel Industrial Wireless Sensor Networks for Machine Condition Monitoring and Fault Diagnostics”, IEEE Trans on Instrumentation and Measurement, Vol. 61, No. 10, 2012, 2787-2798 <https://ieeexplore.ieee.org/document/6215047>
4. Huchel, L.; Helsen, J.; Lindahl, P.; Leeb, S.B., 2019, “Diagnostics for Periodically Excited Actuators”, IEEE Trans on Instrumentation and Measurement, in-press, DOI 10.1109/TIM.2019.2947971 <https://ieeexplore.ieee.org/document/8876701>
5. Moon, J.; Donnal, J.; Paris, J.; Leeb, S.B., “VAMPIRE: A Magnetically Self-Powered Sensor Node Capable of Wireless Transmission”, Proc. of 28th Annual IEEE Applied Power Electronics Conference and Exposition, 2019, 3151-3159 <https://ieeexplore.ieee.org/document/6520751>
6. N211-033 Reference Document S9310-AQ-SAF-010-Rev3 - https://navysbir.com/n21_1/Topic-N211-033-Reference_Document_S9310-AQ-SAF-010-Rev3.pdf
7. N211-033 Reference Document DoD_Directives_Regarding_Wireless_LAN https://navysbir.com/n21_1/Topic-N211-033-Reference_Document_DoD_Directives_Regarding_Wireless_LAN.pdf
8. N211-033 Reference Document 728A-728T-spec-98056B_1 https://navysbir.com/n21_1/Topic-N211-033-Reference_Document_728A-728T-spec-98056B_1.pdf

KEYWORDS: Data Analytics; Condition Based Maintenance; Digital Twin; Wireless Sensing; Predictive Analytics; Rotating equipment

N211-034

TITLE: Submarine Atmospheric Contaminant Scrubbing Technology

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: To provide passive atmospheric contaminant scrubbing technologies to reduce and/or eliminate gas contaminants from 1 to 6 atmospheres absolute (ata).

DESCRIPTION: When a Disabled Submarine (DISSUB) event occurs, several dangerous and potentially lethal atmospheric contaminants can be introduced from fire, battery malfunctions, and other potential sources. These contaminants, if not appropriately managed or removed, can limit the time DISSUB survivors can await rescue. At this time, the submarine force has limited means of removing dangerous atmospheric contaminants, beyond Carbon Dioxide (CO₂), from the DISSUB atmosphere when the internal compartment is either pressurized or there is insufficient available power to utilize other scrubbing technologies. Currently there is no known commercially available technology to passively scrub these contaminants.

The concept of operations (CONOPS) for a DISSUB rescue begin with a senior onboard survivor measuring and monitoring specific atmospheric containments via the USN DISSUB Guard Books. These guard books provide the procedures necessary to support DISSUB survivors in awaiting rescue by rescue forces for a minimum of seven days after the DISSUB event. Additionally, the Guard Books enable the survivors to determine when the atmosphere has been contaminated to a point that it is no longer safe to wait for rescue and therefore escape is required. While awaiting rescue is the preferred method for survivors, the inability to lower or eliminate specific hazardous contaminants may require survivors to attempt escape. Oxygen (O₂) is added to and CO₂ is removed from the internal compartment atmosphere passively via Chlorite candles and Lithium Hydroxide (LiOH) scrubber curtains, respectively. However, there are an additional seven constituents that have been identified by medical personnel as being dangerous to DISSUB survivors when subjected to prolonged exposure to elevated levels. These constituents are defined as the Submarine Escape Action Limit (SEAL) gases and are Carbon Monoxide (CO), Hydrogen Cyanide (HCN), Ammonia (NH₃), Chlorine (Cl₂), Hydrogen Chloride (HCl), Sulfur Dioxide (SO₂) and Nitrogen Dioxide (NO₂).

The program office desires the development of a technology that can provide the ability to passively lower and/or eliminate the 7 SEAL gases identified from a DISSUB internal compartment. In the event of a DISSUB, it is anticipated that the submarine will not have sufficient available power to support an active system. Additionally, the use of a passive system will reduce the production of Carbon Dioxide that would result from survivors using a manually operated system. Due to onboard constraints, the solution(s) should minimize the footprint of the equipment and maintenance requirements. Additionally, to reduce survivor physical stressors and CO₂ generation, the solutions(s) should minimize human system operations while also remaining cognizant of the limited power that may be available. Note that stand-alone battery power for the equipment is acceptable, but the use of Lithium Ion (LIO) batteries is not. Due to internal compartment space constraints, the proposed solution should minimize, as much as practical, the footprint of any required installed equipment as well as maintenance and lifecycle cost requirements.

In terms of technology development efforts, the threshold is the ability to reduce contaminant levels below SEAL 2 levels as quickly as possible and maintain the contaminant levels below SEAL 2 levels for a minimum of seven days. The SEAL 2 levels are CO 150ppm, HCN 15 ppm, NH₃ 125 ppm, Cl₂ 2.5ppm, HCl 35 ppm, SO₂ 30 ppm, and NO₂ 10 ppm. The objective is the ability to reduce and maintain contaminant levels at or below SEAL 1 levels for a minimum of seven days (CO 125ppm; HCN 10 ppm; NH₃ 75 ppm; Cl₂ 1 ppm; HCl 20 ppm; SO₂ 20 ppm; CO₂ 5 ppm). Testing will be conducted via bench-

test in a simulated environment comparable to the anticipated operational environment at NSWC Philadelphia.

In addition to being a safety and duty of care issue, continued advancement and modernization of the USN Submarine Escape and Rescue Program is considered an Assistant Secretary of the Navy core field in support of the larger Undersea Warfare, and directly aligns to both the National Defense Strategy and the Submarine Commander's Intent by defending the homeland; enabling interagency counterparts to advance U.S. influence and national security interests; ensuring USN submarine warfighting readiness and survivability; and strengthening alliances and attracting new partners. The latter was highlighted in the geopolitical outcome following the USN Submarine Escape and Rescue response to the ARA SAN JUAN incident in November 2017.

PHASE I: Develop a conceptual solution that defines the methods and identify the major components required to meet the requirements in the description. Feasibility will be determined by identifying the catalyst required and scientific calculations and modeling to support required contaminant reduction catalyst technologies. The Phase I Option, if exercised, will include refinement of the proposed solution to support Phase II prototype development and the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of the Phase I and the Phase II Statement of Work (SOW), refine, as necessary, the design to build and deliver one prototype for test. Testing will be conducted via bench-test in a simulated environment comparable to the anticipated operational environment at NSWC Philadelphia.

PHASE III DUAL USE APPLICATIONS: Beyond the ability to provide atmospheric containment removal technology to support the Submarine Escape and Rescue program, this technology could also provide benefits to all confined space emergency applications. In addition to the USN and Department of Defense (DoD), PMS391 collaboration initiatives and established Memorandum of Agreements with non-DoD federal and state emergency management organizations – to include the Federal Emergency Management Agency (FEMA), Department of Labor Mine Safety and Health Administration (DoL-MSHA), National Institute of Occupational Safety and Health (NIOSH), and National Aviation and Space Administration (NASA) – can be leveraged to address similar technology needs and requirements. Upon successful prototype testing, the technology is anticipated to be transitioned via backfit installation onboard in-service submarines and implemented as part of new construction for the USS COLUMBIA class and the future SSN(X) class of submarines.

REFERENCES:

1. "Central Atmosphere Monitoring System." U.S. Naval Research Laboratory. 28 November 2018. <https://www.nrl.navy.mil/accomplishments/materials/atmosphere-monitoring/>.
2. "Vehicle Cabin Atmosphere Monitor." NASA. 11 April 2018. 28 November 2018. https://www.nasa.gov/mission_pages/station/research/experiments/35.html.
3. "SSN 774 Class Guard Book, Disabled Submarine Survival Guide, FWD Escape Trunk (Lockout Trunk)." Naval Sea Systems Command, S9594-AP-SAR-G10, 0910-LP-018-5820, Revision 00, 27 April 2006; Change 1, ACN 2/B of 7 Feb 2019; Distribution Statement A: Approved for Public Release, Distribution is Unlimited.

KEYWORDS: Atmosphere in submarines; Atmospheric Contaminant; Emergency Services onboard submarines; Submarine Rescue; Contaminant Removal; Submarine Escape Action Limit (SEAL) gases.

N211-035 TITLE: Compact Battery Power Uncooled 5 kW-Class Laser System

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a compact battery power, efficient uncooled kW class laser system capable of producing > 5 kW output at high atmosphere transparency wavelength.

DESCRIPTION: Compact battery power uncooled kilo-watt (kW) class high energy laser (HEL) prototype systems have been deployed in a variety of platforms as laser weapons to destroy targets and threats. However, high cooling capacity chillers have to be used to dissipate the heat generated by the laser medium and pump sources of these kW-class HEL systems. The size, weight, and power (SWaP) of a HEL system is thus deteriorated by the demand of the cooling chillers on the available SWaP, which also constrains the deployment of such kW-class HEL systems in small, airborne, or unmanned weapon platforms. The DoD has a great demand for compact and robust uncooled kW-class laser system for a variety of applications. Industry will benefit as well from the reduced SWaP requirement of the technology in applications where lasers are used to cut, weld, or ablate material. This project aims to develop kW-class HEL laser sources with improved SWaP and other specifications using innovative laser technology. The Navy is looking for a kW-level laser prototype device with following specifications to be developed; Wavelength: High atmosphere transparency; Average Power Output Threshold: 3 kW (Objective: 5 kW); HEL spectrum wavelength shall be around 1 um, laser beam quality (M2) Threshold: < 1.5); Weight Threshold: 40 lbs (Objective 20 lb); Volume Threshold: 10 inch³ (Objective < 5 inch³); Air cooled compact HEL prototyped system. At present uncooled compact battery power kW class HEL system is not commercially available.

The initial prototype compact 5 kw uncooled battery power HEL system shall be evaluated at a Navy facility to understand the HEL performance and beam quality. During this test and evaluation period Navy will also evaluate the duration of the operation and the system wavelength shifts as system temperature increase. Cycle should be 5 minutes operation at full power and 5 minutes cool down. Maximum surrounding temperature equivalent to eastern summer time (80 to 85 degrees F).

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United

States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for the design of the architecture for a compact ~5 kW-class HEL prototype system that does not require an active cooling system (air cooled). Additionally, the vendor will demonstrate the feasibility of the concept and power scalability of an air cooled HEL prototype system and provide the prototype design of a 5-kW prototype HEL system to NAVY. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype system in Phase II.

PHASE II: Develop and deliver a prototype air cooled approximately 5kw HEL with good beam quality ($M2 < 2$) system for testing and evaluation based on the results of Phase I at NAVY lab. The initial prototype compact 5 kw uncooled battery power HEL system shall be evaluated at Navy facility to understand the HEL performance and beam quality. During this test and evaluation period Navy will also evaluate the duration of the operation and the system wavelength shifts as system temperature increase. Optimize the design and scaling the Phase I laser concept to prototype a compact uncooled battery power laser system capable of producing > 5 kW output power at high atmosphere transparency wavelength that meets the requirements in the Description.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. This support is expected to be in the form of fully developing and transitioning the kW-class laser system for DoD HEL weapon systems. This technology has potential commercial transition to other applications such as industrial material processing (welding, cutting, soldering, marking, cleaning, etc.) and fundamental research.

REFERENCES:

1. Y. Jeong, J. K. Sahu, D. N. Payne, and J. Nilsson, "Ytterbium-doped large-core fiber laser with 1.36 kW continuous-wave output power," *Opt. Express* 12, 6088-6092 (2004).
<https://doi.org/10.1364/OPEX.12.006088>
2. W. Shi, Q. Fang, X. Zhu, R. A. Norwood, and N. Peyghambarian, "Fiber lasers and their applications," *Appl. Opt.* 53, 6554-6568 (2014). <https://doi.org/10.1364/AO.53.006554>
3. V. Gapontsev, D. Gapontsev, N. Platonov, and O. Shkurikhin, "2 kW CW ytterbium fiber laser with record diffraction-limited brightness," in *Proceedings of the Conference on Lasers and Electro-Optics Europe*, (Optical Society of America, 2005).
<https://ieeexplore.ieee.org/abstract/document/1568286/citations#citations>
4. J. Zhang, V. Fromzel, and M. Dubinskii, "Resonantly cladding-pumped Yb-free Er-doped LMA fiber laser with record high power and efficiency," *Opt. Express* 19, 5574-5578 (2011).
<https://doi.org/10.1364/OE.19.005574>
5. T. Ehrenreich, R. Leveille, I. Majid, K. Tankala, G. Rines, and P. F. Moulton, "1-kW, all-glass Tm: fiber laser", in *Fiber Lasers VII: Technology, Systems, and Applications* (2010) (Session 16: Late breaking news).
http://www.qpeak.com/sites/psicorp.com/files/articles/PW%202010%201kW%20Tm_fiber%20laser.pdf

KEYWORDS: High energy laser; Kilo-watt (kW) -class laser; laser weapon system; size, weight, and power (SWaP); uncooled laser; Beam quality (M2).

N211-036 TITLE: Innovative Simultaneous Localization and Mapping Techniques for Unmanned Underwater Vehicles

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: The development of robust Simultaneous Localization and Mapping (SLAM) techniques for assisting the navigation of Unmanned Underwater Vehicles operating in GPS-denied environments.

DESCRIPTION: Despite the considerable effort directed towards UUV navigation, a self-contained solution remains a key challenge. Due to the cumulative error that an inertial navigation system (INS) experiences with time, UUVs typically require regular surfacing to obtain GPS fixes, or the presence of acoustic localization beacons, in order to correct position drift. Such options can be undesirable/unavailable in certain applications (e.g., deep-water and/or Intelligence, Surveillance, and Reconnaissance (ISR) missions). Underwater Terrain Aided Navigation (TAN) methods have also demonstrated the ability to provide accurate navigation resets, though they are limited by the requirement for accurate high-resolution reference bathymetry maps, which are not available for much of the Earth's sea floor. In response to the presently limited navigation capability, this topic will focus on the development of robust SLAM algorithms to assist UUV navigation in GPS-denied environments.

The Navy is rapidly developing and fielding a family of Unmanned Undersea Vehicles (UUV) specifically designed for operations within GPS-denied environments. Advances in underwater sensing technology and computing power have yielded new possibilities in the underwater domain. For instance, advanced sensor processing and new underwater navigation techniques have become available, including SLAM. SLAM broadly refers to the problem of jointly creating (and updating) a map of an unknown environment and estimating the system's position and pose within it. The topic has attracted a flurry of research in the robotics community over the past three decades, including indoor, land-based, aerial and even underwater vehicles. It has been a critical tool in the development of commercial robot vacuum systems, allowing them to operate in any home without prior knowledge of the layout. Other examples include the field of self-driving cars, where SLAM serves as a supplement to GPS navigation, allowing the system to build obstacle maps of the surrounding environment, and continue driving in unmapped areas or when GPS becomes unavailable.

Although SLAM has been proven effective for mobile robots operating in structured environments, the application of these techniques in the highly unstructured underwater domain presents unique challenges. As a result, there is still considerable room for growth in the use of SLAM techniques for UUVs. Some examples of SLAM-based approaches for UUVs include applications for achieving improved velocity-over-ground estimates, and algorithms for improving the accuracy of bathymetric maps generated from a UUV survey. For many UUV SLAM applications, the ultimate goal is to take advantage of the process to reduce position error growth, not necessarily to generate a map of the environment. Likewise, for this topic the UUV will not need to rely on mapping its entire operational environment in order to conduct the

mission. As advances in energy technology continue to increase the endurance and operating range of UUVs, missions will cover wider areas, longer distances, and longer times. It can be assumed that the target UUV system for this effort will feature a navigation-grade INS as the baseline navigation system. PMS 406, Unmanned Maritime Systems program office, seeks the development of robust SLAM algorithms that will increase the mission capabilities of such UUVs by providing additional methods for aiding vehicle navigation. The goal is to increase overall navigational accuracy during a GPS-denied mission beyond what can be achieved with just the standard Doppler Velocity Logger (DVL) aiding to the INS, and provide a means of resetting what otherwise would be unbounded position error growth.

While initial validation of the algorithms can leverage off-line post-processing of vehicle and sensor data, the ultimate system design needs to provide output in-situ that can aid the UUV during the mission. Additionally, the solution should address the limitation of operating in areas without prior knowledge of the bathymetry or specific bottom features. Prior reference information, where available (i.e., any knowledge about natural or man-made features) can be used to enhance performance, however the system must also be capable of operating without any such assistance.

The algorithms developed should be utilized in a wide range of different environments and mission scenarios. This includes both rugged and smooth terrain, as well as cluttered and un-cluttered environments. A list of some potential Navy mission concepts and scenarios will be provided during Phase II. The system should be designed to serve as an aiding source for a UUV navigation framework based on a navigation grade INS. The solution should not be an integral piece of the UUV navigation system to the point that it needs to be operating continuously in order for the vehicle itself to navigate. Instead, the system solution encompassing the SLAM algorithms is expected to provide outputs that can be used as aiding sources into an INS framework.

The proposer will identify the available environmental information, features the algorithms aim to extract and the necessary sensors and sensor processing needed to utilize this information. The company will address how the algorithms are applicable to different UUV mission scenarios across a range of potential operational environments. The company will identify the vehicle behaviors and maneuvering necessary to utilize the algorithms and how these behaviors fit into the context of the overall vehicle mission. The concept will cover how the algorithms address areas where no prior information is available and the handling of both cluttered and un-cluttered environments. The company will identify the output data products of the algorithms and how this data aids the performance of the UUV navigation framework.

It is envisioned that the solution be tailored to aiding a UUV navigation framework based on a commercial off-the-shelf (COTS) Inertial Navigation System. Additionally, the solution may provide a means of saving new maps generated on-board or updating existing maps stored on the system for future use. The proposer will provide a detailed plan for validating the algorithms in a computer simulation environment. This test plan should include the types of vehicle and sensor data, both historical and simulated, that would be required to carry out relevant simulation test cases, and how such data will be acquired and/or generated. Phase II shall also include the development of a plan for at-sea tests of the computer program on government-owned UUVs and a list of validation metrics for such tests.

To ensure interoperability with PMS 406 portfolio, the solution must comply with the Unmanned Maritime Autonomy Architecture (UMAA). UMAA establishes a standard for common interfaces and software reuse among the mission autonomy and the various vehicle controllers, payloads, and Command and Control (C2) services in the PMS 406 portfolio of UxS vehicles. The UMAA common standard for Interface Control Documents (ICDs) mitigates the risk of vendor lock from proprietary autonomy solutions; effects cross-domain interoperability of UxS vehicles; and allows for open architecture (OA) modularity of autonomy solutions, control systems, C2, and payloads. The Navy will provide the open standards for UMAA upon award of Phase I.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Phase I will consist of a concept and feasibility determination on the implementation of SLAM-based techniques for aiding a UUV navigation system during long-duration submerged missions. Feasibility determination will describe a path for development of SLAM algorithms that leverage existing navigation-grade INS solutions and current UUV payload sensor technology to assist in managing position error drift in accordance with the requirements within the Description section of this document.

The Phase I Option, if exercised, will include a detailed outline for a prototype system design for implementation in Phase II and a detailed plan for validating the algorithms in a computer simulation environment. This plan should include the types of vehicle and sensor data, both historical and simulated, that would be required to carry out relevant simulation test cases, and how such data will be acquired and/or generated. Additionally, the company will develop a comprehensive summary of how the proposed solution can address the challenge of improving state-of-the-art UUV navigation systems for long-range missions.

PHASE II: The Phase II effort will focus on implementing the SLAM algorithms proposed and outlined in Phase I by developing and delivering a prototype system. The simulation test plan outlined in Phase I should be used for initial validation and testing of this prototype system during development. Relevant vehicle navigation and sensor data feeds, generated through playback of historical datasets and/or simulation, will be used to create suitable test cases to demonstrate the feasibility of the proposed approach.

A successful Phase II project will demonstrate that the algorithms and prototype system can perform as expected using data representative of a variety of environments and deliver a detailed plan for the integration of the proposed algorithms into a software application compatible with government-owned UUV software architectures. This includes specifying a software interface compliant with the Unmanned Maritime Autonomy Architecture (UMAA). It is envisioned that the solution be tailored to aiding a UUV navigation framework based on a COTS Inertial Navigation System. Additionally, the solution may provide a means of saving new maps generated on-board or updating existing maps stored on the system for future use. Phase II shall also include the development of a plan for at-sea tests of the computer program on government-owned UUVs and a list of validation metrics for such tests.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Assist the Navy in integrating the technology for Navy use. The proposed prototype will be integrated into the software architecture of Navy UUV systems. This includes both research-oriented UUV systems performing Science and Technology missions, as well as acquisition program UUVs conducting Navy missions at sea.

The proposed solution has applicability in a wide variety of commercial as well as defense applications. Organizations that require the use of UUVs for tasks such as inspecting and repairing submerged infrastructure, searching for airplane black-boxes, conducting port and harbor security and collecting environmental data or mapping the sea floor, can leverage this technology to increase navigational and mission reliability. There are significant advantages in transitioning this technology to other DoD agencies, government, and private sector entities to enhance UUV mission capability.

REFERENCES:

1. Paull, Liam, et al. "UUV navigation and localization: A review." *IEEE Journal of Oceanic Engineering* 39.1 (2013): 131-149. <https://www.semanticscholar.org/paper/AUV-Navigation-and-Localization%3A-A-Review-Paull-Saeedi/b141c78f429df09b532b8c996b321eae5983f27e>
2. Palomer, Albert, Pere Ridao, and David Ribas. "Multibeam 3D underwater SLAM with probabilistic registration." *Sensors* 16.4 (2016): 560. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4851074/>
3. Ribas, David, et al. "Underwater SLAM in a marina environment." 2007 IEEE/RSJ International Conference on Intelligent Robots and Systems. IEEE, 2007. https://www.researchgate.net/publication/224296480_Underwater_SLAM_in_a_marina_environment
4. P. Moutarlier and R. Chatila. An experimental system for incremental environment modeling by an autonomous mobile robot. In *Proceedings of the 1st International Symposium on Experimental Robotics*, Montreal, Canada, June 1989. <https://link.springer.com/chapter/10.1007/BFb0042528>
5. R. Smith, M. Self, and P. Cheeseman. *Estimating Uncertain Spatial Relationships in Robotics. Autonomous Robot Vehicles*. Springer-Verlag, 1990. <https://arxiv.org/abs/1304.3111>

KEYWORDS: Unmanned Undersea Vehicles; UMAA; Navigation in GPS-denied environments; Undersea Mapping; SLAM; INS.

N211-037

TITLE: Electronic Warfare Operator Workload Organization and Sharing

RT&L FOCUS AREA(S): Machine Learning/AI

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a methodology for effective and efficient electronic warfare workload organization and sharing that increases the performance of the Electronic Warfare Operator and Supervisor.

DESCRIPTION: The Surface Fleet is deploying a comprehensive suite of integrated and closely coordinated electronic warfare (EW) systems and countermeasures. Employing the latest radio frequency (RF) and digital technology, these systems have vastly improved sensitivity and increased capacity to detect, resolve, classify, and identify signals of interest as well as surveil the RF spectrum over a wide area. This increase in capacity is concurrent with the general increase in RF transmitters in the maritime environment. The RF spectrum, even in open ocean, is now far more crowded than just a few years ago. Every small craft (fishing boats, small merchantmen, patrol craft, etc.) can now afford to install commercial radar and communications equipment. The problem in navigational choke points, such as highly trafficked straits and the approaches to major ports, is severe and often complicated by the proximity of shore-based transmitters. In addition, future naval engagements will be marked by an unprecedented array of threat transmitters that use the electromagnetic spectrum.

Increased levels of EW system performance combined with the proliferation of RF transmitters (threat, friendly, and civilian) presents a significant increased burden on the EW operator (EWOP). The EWOP now has access to more electronic support (ES) information of a greater depth than ever before. Operator overload and fatigue are serious problems. While some of this data can be processed automatically by machine learning or adaptive algorithms, the Navy cannot remove the human decision-maker entirely from the loop and the EWOP remains a critical element in surface combat. Fortunately, the EWOP teams with an EW supervisor (EWSUP) to share the workload and coordinate more broadly with the combat information center. Applied effectively, the EWOP-EWSUP team is an effective element for eliminating errors, maximizing situational awareness, minimizing response times, and ensuring proper execution of EW doctrine during complex engagements. During normal operations, this teaming reduces fatigue. However, this reduction is predicated on effective organization, prioritization, and sharing of the EW battlespace information and responsibilities. This problem is similar to an air traffic control center's organization and performance. However, air traffic control is based on a structured hierarchy of tasking, fairly predictable patterns (by intention), relatively constant workload, and cooperative "targets". This is not the case during EW engagements and no comparable commercial application can be easily adapted for the EWOP-EWSUP team structure.

The Navy seeks an innovative method (realized in prototype algorithms and demonstrated on surrogate hardware and displays) to efficiently organize, prioritize, and share information and tasking between the SLQ-32 electronic warfare system EWOP and EWSUP to assure situational awareness, coordinate EW

assets, and efficiently execute engagements. The solution must prioritize tasking by taking into account that the EWSUP is the senior watchstander, typically responsible for mission planning, response coordination (including countermeasures management), sensor networking and cueing, EW doctrine, and overall coordination with the combat information center. The EWSUP may also be called upon to assist in the evaluation of problematic emitters and environmental conditions. However, the solution must also be dynamic and recognize and adapt to fluctuating shifts in workload resulting from the natural progression of complex engagements. The solution must also be flexible to the addition of future EW capabilities and assets. Finally, while it is not intended that the solution include embedded training, it should accommodate embedded training by including the ability to display Surface EW Team Training (SEWTT) controls from either the EWOP or EWSUP console so that the EW Training Supervisor or instructor can monitor and manipulate (i.e., start, stop, pause, reset, add elements, etc.) embedded training scenarios while in progress.

It should be noted that acceptable solutions should demonstrate a science-based knowledge of human perception, human cognition, team dynamics, and decision-making. “Hard wired” solutions that organize and manage the EWOP-EWSUP interaction based on fixed assignments and pre-prioritizations of functions are unacceptable. The goal of this effort is to complement and facilitate the relationship between the EWOP-EWSUP team in a manner that elevates their performance to a level that they could not otherwise achieve on their own. Testing will consist of controlled and monitored execution of the prototype solution with human operators utilizing surrogate display hardware. Final validation of the prototype will be demonstration of the workload sharing prototype on the surrogate display hardware, as witnessed by Government subject matter experts and program managers.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Propose a concept for an EW workload organization and sharing application that meets the objectives stated in the Description. Feasibility shall be demonstrated by a combination of analysis, modelling, simulation, and evaluation of initial workload sharing use cases. The feasibility analysis shall include predictions of operator performance in use of the application. The Phase I Option, if exercised, will include the initial design specification, decision trees, and capabilities description necessary to build a prototype solution in Phase II.

PHASE II: Develop, deliver, and demonstrate a prototype of the concept for an EW workload organization and sharing application meeting the requirements contained in the Description. A software prototype shall be demonstrated on surrogate display hardware (supplied by the performer) and delivered to the Government along with full software interface descriptions and any ancillary software needed to demonstrate the application. It should be noted that this effort may require the development and delivery of synthesized EW scenarios and emitter data to be used in demonstration of the prototype solution. Government subject matter experts and program managers will witness demonstration of the prototype technology on the surrogate display system.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Government use. Since the Phase II effort result is a prototype that is not necessarily demonstrated on a tactical system, assist in integrating the EW workload organization and sharing application into the EW display tactical code. Assist in certification of the resulting tactical code. Assist the Government in testing and validating the performance of the resulting application as integrated into the EWOP and EWSUP consoles.

The workload organization and sharing software can also be customized for additional applications such as other military systems (e.g., radar systems) and for commercial applications such as air traffic control systems, power grid control stations, train and mass transit dispatch systems, and complex security systems.

REFERENCES:

1. Endsley, Mica R. "Designing for Situation Awareness: An Approach to User-Centered Design, Second Edition." Boca Raton: CRC Press, 2011. <https://www.crcpress.com/Designing-for-Situation-Awareness-An-Approach-to-User-Centered-Design/Endsley/p/book/9781420063554>
2. St. John, Mark and Smallman, Harvey. "Staying Up to Speed: Four Design Principles for Maintaining and Recovering Situation Awareness." Journal of Cognitive Engineering and Decision Making, Volume 2, Issue 2, 1 June 2008, pp. 118-139. <https://journals.sagepub.com/doi/pdf/10.1518/155534308X284408>

KEYWORDS: Electronic Warfare; Workload Sharing; Decision-Making; Team Dynamics; Human Cognition; Embedded Training

N211-038

TITLE: Next Generation Laminated Bus Bar Technologies

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Increase the reliability and confidence of laminated bus bars through the development of new insulation materials and Non-Destructive Testing (NDT) methods.

DESCRIPTION: DDG 1000 Class utilizes an Integrated Power System (IPS) to generate and distribute power to the propulsion system, ship service distribution system, and combat systems. Multi-layer, multi-conductor, laminated bus bars are used within the IPS system to distribute local high voltage (4160 VAC RMS) power distribution within switchboards, propulsion motors/drives, and other high voltage equipment. We currently use multi-layer, multi-conductor, laminated bus bars in the system.

While laminated bus bars are used throughout the power industry, recent bus bar failures have highlighted the need for new technologies that will increase the reliability of bus bars in a non-sterile, shipboard environment. ASTM B187 provides guidance for copper commercial bus bars. Development areas of interest are insulation materials, conductor-connection interfaces, and associated NDT procedures.

Bus bars must be capable of handling various voltages, frequencies and currents dependent upon their application including maximum layer-to-layer potentials of 10.5 kV peak to ground, +/- 6500 VDC, 60A and pulse width modulation (PWM)-switched output waveforms of 3300 VAC 0-18Hz 450A. Nominal PWM switching frequency between the range of 1kHz and 20kHz.

Installed bus bars must be capable of passing qualification testing for a shipboard environment including to MIL-S-901 Grade A, Type A, Class 1 Shock, MIL-STD-167-1 Vibration, and MIL-STD-810 for Temperature and Humidity. Bus bars shall be mechanically compliant / flexible to provide excellent resistance to stresses from the above shock and vibration standards as well as installation handling. Bus bars shall meet the requirements of MIL-DTL-23928.

Quality & Assurance (Q&A) processes and NDT technologies should be developed. This path will allow for the identification of insulation flaws prior to installation and the ability to verify bus bar condition through service life of current bus bars. High fidelity Q&A processes reducing the number of defective units being delivered to the fleet would increase confidence of delivered bus bars. Currently, partial discharge testing based on IEC 60270 is used to determine insulation material condition. New scanning technologies or test methods are needed to verify insulation condition which would increase confidence in in-service and spare bus bars.

PHASE I: Develop a concept for alternative insulation materials, connector interfaces, and NDT method in accordance with specifications and requirements outlined in the topic description section. Demonstrate the feasibility of the developed technology to meet the Navy's needs through material testing. The Phase I Option, if exercised, will outline the requirements and specifications to build prototypes in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop the prototype bus bar to meet the Navy's needs and verify in accordance with MIL-DTL-23928. Mature NDT technology and demonstrate the capability to detect bus bar insulation flaws. Demonstration/verification testing will occur at a company-provided facility. Refine the fabrication process and test procedure with a focus on creating consistent product to aid transition in Phase III. Prepare a Phase III development plan to transition the technology for Navy and potential commercial use.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the bus bar technology to DDG 1000 class destroyers and future Navy high voltage systems. The final product will be capable of meeting all relevant qualification testing including shock, vibration, electromagnetic interference (EMI), humidity, and temperature. Support the development of documentation including, but not limited to; technical manuals, parts lists, drawings, training guides, and logistics documents.

The use of high voltage distribution systems and electric propulsion is becoming more frequent in the offshore and shipping industries. Reliable bus bars and the ability to verify manufacturing quality will be required to support this expansion. The technology developed to support the Navy is directly applicable to these industries and the shore-side power industry.

REFERENCES:

1. Wang, Jianing; Yu, Yu Shaoling; Zhang, Xing. "Effect of Key Physical Structures on the Laminated Bus Bar Inductance. IEEE International Power Electronics and Motion Control Conference. Published 14 July 2016. Accessed 19 November 2019.
<https://ieeexplore.ieee.org/document/7512886>
2. Chih-Ju Chou and Chien-Hsun Chen. "Measurement and Analysis of Partial Discharge of High and Medium Voltage Power Equipment. IEEE International Symposium on Next Generation Electronics. Published 25 June 2018. Accessed 19 November 2019.
<https://ieeexplore.ieee.org/document/8394749>
3. N211-038 Reference Document – Supplemental Data https://navysbir.com/n211/Topic-N211-038-Reference_Document_Phase-1-Data.pdf

KEYWORDS: Laminated Bus Bar; High Voltage Insulation; High Voltage Connectors; Shipboard Power Distribution; Partial Discharge Testing; Non Destructive Testing.

N211-039 TITLE: 24/7 Reachback Artificial Intelligence Support Environment for Anti-submarine Warfare (ASW)

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a 24/7 reachback artificial intelligence (AI) support environment to modernize anti-submarine warfare (ASW) in-service and logistics troubleshooting both to support the large variety of fielded baselines and configurations; enable machine learning to inform best fixes; and drive future design improvements to tactical sonar suites.

DESCRIPTION: A 24/7 Reachback AI Support Environment can modernize the in-service and logistics support (ILS) infrastructure so that sailors and ILS personnel have rapid alignment regarding the particular baseline and configuration in question. Commercial AI support tools are increasingly used in industry but these tools are specific to the industry in which it is created. The tools are needed for ASW support. The modernized environment would be based on an ontology that allows for data mining and machine learning regarding issues with greatest Fleet impact, both from a standpoint of understanding the breadth and scope of impact as well as elevating the most appropriate fixes.

As the 24/7 Reachback AI Support Environment accrues information, evidence collected could drive design improvements.

The technology sought will increase mission capability by accelerating resolution of system casualties identified by sailors across the many different fielded variants. The technology will also create a Navy-wide database on which artificial intelligence and machine learning can operate to identify root causes to inform future acquisition decisions related to improving system availability.

Navy surface combatants engage in anti-submarine warfare (ASW) using variants of the AN/SQQ-89, a complex system of systems composed of processing software, processing hardware, and sensitive sensor arrays. When operating properly, the ASW sensor suite gives a Fleet combatant a powerful capability to detect, classify, localize, and attack submerged threats.

The in-service and logistics infrastructure for the AN/SQQ-89 has evolved over decades, building on the Cold War sonar capability fielded in the 1950s as the AN/SQQ-26 sonar. In the two decades since the end of the Cold War, a majority of fielded AN/SQQ-89 systems were legacy systems, with problems that had remained relatively stable.

Initial introduction of the A(V)15 modernization to the AN/SQQ-89 in 2009 brought modernized capabilities that the Fleet welcomed, including introduction of the Multi-Function Towed Array (MFTA). The A(V)15 leverages commercial off-the-shelf (COTS) processing hardware. Though relatively

inexpensive and very powerful from a processing standpoint, COTS infrastructure drives a relatively rapid pace of technology updates.

The rapid pace of updates required by COTS infrastructure has enabled introduction of numerous improvements. However, the proliferation of distinct variants has made the ILS challenge increasingly complex. Support personnel using infrastructure designed to support legacy baselines have identified potential for significant improvement in in-service and logistics support (ILS) outcomes should a modernized reachback capability be developed.

When problems arise, sailors seek reachback support from ILS personnel who work 24/7 to provide timely guidance to resolve Fleet casualty reports (casreps). When new parts are required, the ILS team speeds them on their way. It is crucial that communication between the Fleet and the ILS team is robust, ensuring that the ILS specialist is 1) troubleshooting based on the proper baseline and configuration and all pertinent data; and 2) ensuring that any replacement parts are appropriate to the baseline and configuration in question. As diagnosis of many system casualties involve interaction with displays, it is important that the ILS specialist have ready access to the particular displays associated with the system the Fleet sailors are attempting to fix.

The technology will be tested using the IWS 5.0 Advanced Capability Build (ACB) step testing process. The seminal transition event will be validation by the Government that the technology performs as required. Testing will include user exploration of the tool, examination of the fault isolation capabilities and associated accuracy, and comparison of the tool menus to the tactical system menus to ensure consistency.

Finally, the information accrued by the modernized reachback capability should be organized into an ontological framework that facilitates machine learning and artificial intelligence to enable analysis of casualties across the Fleet, their root causes, and prioritization of investments to make the overall system more robust. A particular challenge, required to be provided by the new tool, is providing timely and appropriate ILS for the MFTA. As a towed sensor, the MFTA operates hundreds of feet below the ocean surface, necessarily deployed and retrieved through the punishing conditions in the wake of the combatant. The OK-410 handling system associated with the MFTA, while robust, has numerous moving parts. The MFTA operates in the ocean depths where submerged threats often seek to hide, and is therefore particularly valued by the Fleet. Initial transition of the 24/7 Reachback AI Support Environment will likely focus on systems related to MFTA and other towed systems.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for a 24/7 Reachback AI Support Environment that meets the requirements in the Description section. The concept will show feasibility through analytical modeling; developing and documenting infrastructure concepts; proposed ontological framework; and architectures that support both sailors, ILS specialists, and analysts. The Phase I Option, if exercised, will include the initial system specifications and a capabilities description to build a prototype in Phase II.

PHASE II: Develop and deliver a prototype 24/7 Reachback AI Support Environment with embedded machine learning meeting the requirements for ASW as stated in the Description. Demonstrate the prototype performance across a subset of the total SQQ-89 ILS historical findings and demonstrate the prototype is fit for use by Fleet operators, ILS specialists, and acquisition analysts as discussed in the Description. If needed, coordination with the Government will occur to conduct testing at a Government or company-provided facility to validate the prototype capability. Data sets extracted from Cruiser/Destroyer casualty reports will be used to validate the prototype's capabilities. The Government will provide the data. Demonstration of the prototype performance will take place at a Government- or company-provided facility.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use in ASW. Demonstrate and report on performance during laboratory testing. Integrate the prototype into the IWS 5.0 surface ship ASW combat system ILS infrastructure, which will drive updates to sensor systems, handling equipment, and the Advanced Capability Build (ACB) program used to update the AN/SQQ-89 Program of Record.

This technology can be used to support a broad range of commercial and military industries where support originally designed for complex legacy systems needs to be modernized to include a proliferation of unique models.

REFERENCES:

1. "AN/SQQ-89(V) Undersea Warfare / Anti-Submarine Warfare Combat System." United States Navy Fact File. 15 January 2019. https://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=318&ct=2
2. Serban, Floarea et al. "A survey of intelligent assistants for data analysis." ACM Computing Surveys (CSUR) 45.3, 2013; p, 31. https://www.worldcat.org/title/survey-of-intelligent-assistants-for-data-analysis/oclc/942490000&referer=brief_results
3. Borrás, Joan; Moreno, Antonio and Valls, Aida. "Intelligent tourism recommender systems: A survey." Expert Systems with Applications 41.16, 2014; pp. 7370-7389. https://www.worldcat.org/title/intelligent-tourism-recommender-systems-a-survey/oclc/5606588315&referer=brief_results
4. "MFTA: The US Navy's New Towed Array for Naval Detection." Defense New Daily. Updated September 23, 2019. <https://www.defenseindustrydaily.com/mfta-the-us-navys-new-towed-array-for-naval-detection-04956/>

KEYWORDS: In-service and Logistics Support; Artificial Intelligence; Anti-Submarine Warfare; ASW; Machine Learning; Casualty Reports; Towed Systems

N211-040 TITLE: Submarine Deep Escape

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Biomedical

OBJECTIVE: Develop an innovative solution that will improve the ability to successfully accomplish single-man escape to 600 feet of seawater (fsw) of survivors from a disabled submarine and potentially increase the ability to provide safe deep escape beyond 600 fsw.

DESCRIPTION: All United States Navy (USN) submarines are provided with the equipment certified to support single-man escape of Disabled Submarine (DISSUB) survivors down to a depth of 600 fsw. This equipment is comprised of a flood valve, auto-vent valve, single-man escape suit, and an escape suit hood inflation system, among other components.

The escape trunks onboard are capable of supporting escape of two survivors (also referred to as 'escapers') per escape cycle. Two escapers, outfitted with escape suits, enter the escape trunk from the internal submarine compartment. After entering, the lower hatch of the escape trunk is closed and the escapers, using hood inflation valving connected to a 700-pound ship's service air source, inflate the escape suits. The escape suits fully inflated provide up to 70 pounds of buoyancy to each escaper. This buoyancy is to allow for the rapid ascension of the escaper to the water surface to minimize the risks associated with decompression obligations. After the escape suits are fully inflated, the escape trunk flood valve is opened to fill the trunk with external seawater up to the trunk auto-vent valve. The auto-vent valve is calibrated to ensure that the flooding of the trunk stops at a pre-determined level and when the auto-vent valve fully lifts, the rapid pressurization cycle of the remaining air bubble begins. At 600 fsw, the pressurization cycle is designed to be no greater than 20 seconds before the escape trunk pressure is equalized with the external sea pressure. Once equalized, the upper hatch opens and the escapers automatically exit the upper hatch and ascend to the surface. The design of the escape suits allows the escaper to breathe normally during ascent.

Human subject testing has been successfully accomplished to prove the capability of escape down to 600 fsw. However, that testing highlighted that it is physically challenging and as the depth of the escape is increased, the risks associated with decompression obligations and mortality increase exponentially. In addition to the body's ability to withstand the designed rapid pressurization, the ability to withstand the heat loads generated by the pressurization cycle is also of a concern. Although the mortality risk increases significantly as depths exceed 600 fsw, it is anticipated that successful escape may be achievable, based upon experimental trials and the theorized mechanical robustness of the submarine escape system and escape suits. At this time, escape protocols only allow for escape from depths greater than 600 fsw in situations when impending death is inevitable if survivors do not initiate immediate escape. Due to advances in technology and biomedical research, it may be possible to decrease the associated risk with escape from deeper depths.

The rescue of survivors from a DISSUB is the preferred method for the Navy. However, internal conditions of the DISSUB may require some, if not all, of the survivors to initiate escape in lieu of waiting for rescue forces to arrive. The time necessary to mobilize rescue forces may be in excess of the available time for survivors to remain onboard the DISSUB. Due to the risks associated with deep escape, the program office is in need of technology that will decrease the risks associated with escape to 600 fsw and potentially increase the ability to provide safe escape deeper than 600 fsw with an objective to allow

for reasonable safe escape to 1000 fsw. This may involve addressing the physiological stressors associated with deep escape, the mechanical components used to accomplish escape, or a combination of both.

In addition to being a safety and duty of care issue, continued advancement and modernization of the USN Submarine Escape and Rescue Program is considered an Assistant Secretary of the Navy core field in support of the larger Undersea Warfare and directly aligns to both the National Defense Strategy and the Submarine Commander's Intent by defending the homeland, enabling interagency counterparts to advance U.S. influence and national security interests, ensuring USN submarine warfighting readiness and survivability and strengthening alliances and attracting new partners. The latter was highlighted in the geopolitical outcome following the USN Submarine Escape and Rescue response to the ARA SAN JUAN incident in November 2017.

PHASE I: Develop a design concept, with notional feasibility determined via computer based modeling and simulation, that will support a conceptual solution that improves the ability to escape to 600 fsw and potentially increases the ability to provide safe deep escape beyond 600 fsw. Considerations of the potential design concept should include internal compartment space constraints and minimal increase to stowage requirements, maintenance requirements, and lifecycle costs. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of the Phase I and the Phase II Statement of Work (SOW), develop a breadboard design based upon the conceptual solution, including the major components identified, to provide a representative simulation of the proposed solution. Following breadboard testing, refine, as necessary, the design to build and deliver one reduced scale prototype for testing. Due to risks associated with human subject testing, all testing accomplished will be via modeling and simulation in a computer-aided or laboratory environment. The ability to use human subjects in a lab-created or real-world environment would require approval beyond the scope of the SBIR program.

PHASE III DUAL USE APPLICATIONS: The dual use application of proposed technology is dependent upon the technology identified. However, the ability to decrease the risks associated with escape from a USN Submarine has follow-on benefits to partner ally submarine forces and other organizations who support confined space personal recovery, both within and external to the USN and DoD. Conduct further testing and certification in accordance with requirements set forth by the USN Undersea Medical community. It is anticipated that this certification will require human subject testing to be performed at the Pressurized Escape Submarine Tower (PSET) and/or Navy Experimental Dive Unit (NEDU).

REFERENCES:

1. "S9594-AP-SAR-G10, 0910-LP-018-5820, Revision 00, SSN 774 Class Guard Book, Distressed Submarine Survival Guide FWD Escape Trunk, Change A of 1 October 2013, ACN2/B of 7 Feb 2019. <https://www.yumpu.com/en/document/read/11295816/774cl-fwd-guard-book-s9594-ap-sar-g10>
2. "Submarine Rescue Diving and Recompression System Operational Requirements Document." Chief of Naval Operations, Serial Number 489-87-98, 3 Jun 1998. https://www.navysbir.com/n21_1/N211-040-REFERENCE-2-Operational-Requirements-Document.pdf

KEYWORDS: Submarine Rescue; escape from 600 fsw; submarine escape suits; rapid pressurization; decompression; submarine escape trunk

N211-041 TITLE: Compact Cryocooler for Maritime Operations

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a scalable, compact, high-efficiency, low-cost, cryocooler capable of operations in maritime environments.

DESCRIPTION: Superconductivity is a unique state of matter, where at cryogenic temperatures a material has near zero resistance allowing a large current to pass through a relatively small wire. The ability to pass large currents through the wire enable it to be used for magnetic applications. Two temperature ranges of superconducting materials exist as low temperature superconductors (LTS) and high temperature superconductors (HTS). HTS materials begin to transition from a resistive to zero resistance superconducting state around 100 K, while LTS transition begins at much colder temperatures typically below 15 K. The exact transition temperature is material specific; however, regardless of material, superconductive systems require cryogenic environments. The elevated operating temperature of HTS makes the cryogenic cooling systems orders of magnitude more efficient than LTS.

The Navy plans to use HTS in several application including degaussing operations of large surface combatant ships. These systems require large cryocoolers and are less sensitive to the impacts of cryocooler size, weight, and efficiency than tactical applications. As the Navy explores future smaller-scale applications, there are commensurate requirements for novel compact cooling solutions. One such area is the Navy's development of superconducting magnets on the order of 6" to 24" diameter that will require cooling to cryogenic temperatures between 20-50 K with 40-80 W of available cryogenic cooling power. These magnets can serve a multitude of different applications and may be subject to varied operational environments.

Currently, commercial cryocooler technologies exist that can provide cooling on the order of 20 W at 60 K within a total system volume of 320 in³ and mass of 6.4 kg. Configuration of these coolers allows the entire cryocooler package to fit in a 5" diameter envelope. In addition to being small profile, these coolers boast a mean time to failure (MTTF) of 120,000 hrs, giving them excellent long-term reliability. Prior Navy developments targeted large-scale applications of superconductivity requiring cryocooling solutions from 300 to 700 W at 50 K, with targeted efficiencies of 30% of Carnot. Currently there is an order of magnitude gap in cooling capacity between COTS technology and the Navy-developed technology that attains high levels of efficiency.

The Navy is seeking technical solutions that can provide scalability to bridge the gap between the existing cryocooler technologies and the anticipated requirements to field future systems. The Navy anticipates several environmental constraints that will be imposed on the cryocooling technology including various mounting angles, changes in gravitational orientation due to platform roll and pitch, large shock forces, and operation in a high magnetic field environment, on the order of 2 T. Consequentially, any fully

realized product needs to pass military shock requirements as listed in MIL-S-901D Grade A and military vibration standards established in MIL-STD-167-1A. Any product also needs to function independently of gravitational orientation (full 360 degrees, six degrees of freedom) and in the presence of magnetic fields approaching 2T. A viable solution must also be capable of operation with a range of cooling water temperatures from 4°C to 40°C. The solution should be less than 350 in³ total volume while fitting within a 6 in diameter container, weigh less than 6 kg and possesses the ability to operate where input power availability may be greatly diminished. Therefore, designed efficiency targets should be greater than 25% of Carnot. The technical solution should include flexibility to be designed around input power that may include DC (12V, 24V, 48V), or AC (single-phase 120 V, or three-phase 440 V). The technical solution should target approximately 100 W (± 20 W) of cooling at 50 K validated by experimental testing, which will include the injection of heat and temperature recording of the cryogenic space.

PHASE I: Develop a concept and complete a feasibility analysis of the cryocooler concept to meet desired performance specifications detailed in the Description. Design and manufacturing concepts should be assessed through modeling, analysis, and benchtop testing. Size, weight, nominal performance at design as well as capacity map from no-load to 300 K, and input power shall be documented. Perform a cost estimate for both prototype development and full-scale production. The Phase I Option, if exercised, includes a detailed design and specifications to build a prototype during a Phase II effort.

PHASE II: Develop, design, and fabricate a functional prototype of a compact cryocooler based on the results of the Phase I and Phase II Statement of Work (SOW) and complete characterization testing of key performance parameters at the proposer's facility or other suitable test center identified by the proposer. The designed capacity map developed in Phase I shall be updated and experimentally validated through testing of the initial prototype. Deliver the prototype to the Navy for further testing, along with maintenance and integration relevant designs and drawings. Test results, lessons learned, and design update recommendations derived from lessons learned during prototype testing shall be integrated into an additional prototype unit.

PHASE III DUAL USE APPLICATIONS: Aid in the transitioning of the technology for Navy use, as well as engage in market research, analysis, and scouting of potential industry partners to stand up production level manufacturing capabilities and facilities. The final product will be tested and verified for Navy use through the completion of qualification according to the relevant military specification and standard documents. This technology has value in any compact cryogenic application, including; to portable magnetic resonance imaging (MRI) systems, superconducting magnetic energy storage (SMES), and a wide variety of other applications, both commercial and military.

REFERENCES:

1. Hawsey, R.A. and Morozumi, S. "The Energy and Environmental Benefits of Superconducting Power Products." *Mitigation and Adaptation Strategies for Global Change*, vol. 10, pp. 279-306, 2005/04/01. <https://link.springer.com/article/10.1007/s11027-005-9031-4>
2. Fitzpatrick, B.K.; Golda, E.M. and Kephart, J.T. "High Temperature Superconducting Degaussing–Cooling Two HTS Coils With One Cryocooler for the Littoral Combat Ship." *AIP Conference Proceedings*, vol. 985, pp. 277-283, 2008/03/16. <https://aip.scitation.org/doi/10.1063/1.2908558>
3. "Datasheet: Cryotel DS 30." Sunpower- Ametek, 2020. <https://www.sunpowerinc.com/-/media/project/ameteksxa/sunpower/ameteksunpower/productdocuments/ds-30w-datasheet-sm-2.pdf?la=en>
4. "MIL-S-901D Grade A, Military Specifications: Shock Tests H.I. (High-Impact) Shipboard Machinery Equipment, and Systems, Requirements for." http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-S/MIL-S-901D_14581/

5. "MIL-STD-167-1A, Department of Defense Test Method Standard: Mechanical Vibrations of Shipboard Equipment." http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-167-1A_22418/

KEYWORDS: Compact Cryocooler; High Temperature Superconductor; HTS; Superconductivity; Cryogenics; Magnetics; Cryo-refrigeration; low temperature superconductors; LTS

N211-042 TITLE: Sensitivity and Resolution Improvements for Small-Aperture Marine RADAR

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Achieve higher detection sensitivity and angular resolution in small-aperture marine RADAR applications.

DESCRIPTION: Modern submarine navigation systems leverage commercial off-the-shelf (COTS) magnetron RADAR technology to detect moving vessels and distant shorelines. In this architecture, long-range detection sensitivity is limited by the effective radiated power (ERP) of commercially available RADAR products, many of which have been discontinued or experienced power reduction in recent years due to the emergence of low-cost broadband and pulse compression devices. Furthermore, submarine surface navigation RADAR systems must operate within a pressure proof volume (i.e., "pod") that remains permanently mounted on a penetrating mast. There are acquisition and shipbuilding advantages to using smaller pod volumes, and therefore smaller antennas, but this comes at the expense of angular resolution, which degrades with shorter diameters. The use of large and powerful open array marine RADARs is not practical in these applications, yet International Electromagnetic Commission (IEC) standards still require strict RADAR performance against small, distant and closely spaced contacts. This puts IEC compliance out of reach for these small-aperture RADAR systems.

The Navy seeks innovative concepts that increase detection sensitivity and angular resolution of small aperture RADARs without breaking the pod-based sensor model. Reliable detection and resolution of navigation buoys (5 m²), small vessels (2.5 m²) and channel markers (1 m²) is required at IEC compliant ranges. The challenge is to overcome physical sensor limitations by using new architectures, innovative apertures, or digital processing to improve detection and resolution performance on these required targets. Doppler beam sharpening (DBS) algorithms can improve bearing resolution and are now available digitally in commercial marine RADAR products. Further resolution improvement is attainable using knowledge-aided DBS techniques. Sensitivity improvements are achievable using minor modifications to COTS devices. For example, the incorporation of low-noise amplifiers, coherent processing threads, or multi-static/netted sensor architectures all offer sensitivity advantages. The use of frequency and phase-modulated waveforms is shown to provide predictable improvements in processing gain and range resolution. The technology introduced by this topic will help retain navigation RADAR performance for the warfighter without forfeiting the cost and shipbuilding advantage of small and COTS-based designs. This technology is also applicable to the commercial RADAR industry as a means of reducing sensor size and improving the standard for safe navigation.

In the submarine application, the available volume for a rotating antenna is less than 20" in diameter and 8" in height. Analog-to-digital conversion must be performed within the sensor pod using a commercial RADAR processor assembly or similar small form factor device that would fit in a 20" diameter by 3" high volume. Digital RADAR video and data processing outputs will be distributed from the pod to inboard processors, so low network speeds (10 GbE or less) are preferred to enable integration with legacy platforms. Solutions that rely on commercially available components are preferred because of cost and availability, but not required. Digital processing capabilities must be implemented on Government-furnished servers or field-programmable gate arrays (FPGA) using open interface standards to allow periodic and modular software/firmware upgrades.

PHASE I: Conduct innovative research, design, and modelling to demonstrate the proof of concept. Evaluate the feasibility of using the concept to improve sensitivity and resolution of small-aperture X-band RADAR. The concept shall include simulated performance analysis, performance estimates for

achievable angle resolution, and range of first detection of required targets identified in the Description Section. Develop system architecture diagrams to identify technical challenges, risks, and any cost/performance trades associated with the technology. The Phase I Option, if exercised, will include development of the capability description, design specifications, and performance requirements for a Phase II prototype.

PHASE II: Mature the concept by building and testing a functional prototype based on the Phase I design and the Phase II Statement of Work (SOW). Conduct demonstrations and collect measurements in simulated and over-water environments to validate the prototype. Ideally, Phase II testing will consist of field measurements that demonstrate the ability to meet Phase I performance predictions and applicable IEC 62388 performance metrics in a relevant over-water environment. Controlled laboratory experiments may also be used to verify and validate performance estimates where field measurements are not practical. Develop a transition plan for technical insertion on Navy platforms, and report on the overall commerciality and suitability of the prototype for tactical fielding. Transition the final solution to appropriate platforms and end users.

PHASE III DUAL USE APPLICATIONS: Assist the Navy to transition the concept from prototype development to full production. The final design will be produced with tactical form, fit and function. Factory acceptance testing is expected to formally verify system performance and survivability against MIL-STD-167-1A, MIL-STD-461F, MIL-STD-464C, and MIL-STD-810G environmental standards.

The targeted platforms for Phase III transition are VIRGINIA and COLUMBIA class submarines, and so a temporary alterations (TEMPALT) fielding may also be used to reduce production technical risks. While the primary motivation for this technology is to improve performance of military marine RADARs, commercial applications also exist in any industry where a sensor aperture is limited by physical constraints, for example, small aperture RADARs are used in modern automobiles to automatically detect and resolve moving objects, predict collisions, and assist in driver decision making. Similarly, the use of commercial unmanned aerial vehicles (UAVs), or drones, has gained interest in many service industries. The technology described in this topic can be used to improve the performance of electromagnetic sensors in these non-military applications.

REFERENCES:

1. Kazimierski, Witold and Stateczny, Andrzej. "Analysis of Beam Sharpening Effectiveness in Broadband Radar on Inland Waters." 16th International Radar Symposium (IRS), Dresden, Germany, Volume: pp. 870-875, June 2015.
https://www.researchgate.net/publication/283150133_Analysis_of_Beam_Sharpening_Effectiveness_in_Broadband_Radar_on_Inland_Waters
2. Chen, Hongmen et al. "Knowledge-Aided Doppler Beam Sharpening Super-Resolution Imaging by Exploiting the Spatial Continuity Information." Sensors (Basel). 2019 Apr; 19(8): 1920.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6514580/>
3. Abdelbagi, Hamid Eltayib. "FPGA-Based Coherent Doppler Processor for Marine RADAR." Thesis, University of Dayton, School of Engineering, May 2016.
https://etd.ohiolink.edu/etd.send_file?accession=dayton1461182845&disposition=inline
4. Kilani, Moez Ben. "Multistatic Radar Optimization for Radar Sensor Network Applications." Thesis, University of Quebec, April 30, 2018.
http://espace.etsmtl.ca/2115/1/BEN%20KILANI_Moez.pdf
5. Zhang, Bin; Hua, Dong and Tong, Liu. "Research on marine solid state radar and its application." IEEE Xplore Digital Library. 2013 Third World Congress on Information and Communication Technologies (WICT 2013), February 3, 2020. <https://ieeexplore.ieee.org/document/7113098>

KEYWORDS: Marine RADAR; Beam sharpening; Frequency Modulate Continuous Wave; FMCW; Collision Avoidance; Coherent integration; Field-programmable gate arrays; FPGA

N211-043

TITLE: Intelligent Corrosion Simulation and Design Tool

RT&L FOCUS AREA(S): Machine Learning/AI

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop an Intelligent Corrosion Simulation and Design Tool that will read Computer Aided Design (CAD) drawings, select the corrosion modes that the materials are likely to encounter, and assign the service environment to the selected computational engine.

DESCRIPTION: Currently available commercial options for computational corrosion modeling are based on modeling approaches that require detailed materials science knowledge for the end users, apply narrowly focused subset of relevant corrosion modes for materials of interest, and are not context sensitive to select which modes of corrosion are most likely for materials of interest.

The cost of corrosion to the Naval fleet exceeds \$9.5B/year, with 40% of that cost avoidable with improved corrosion design. The current state of the art for computational corrosion simulations requires the end user to have advanced knowledge of materials science, service environment chemistry and corrosion countermeasure options. Designing warship subsystems for corrosion cost avoidance requires detailed knowledge of construction material performance to each mode of corrosion damage, service environments in which the materials are intended to be used, available corrosion countermeasure technologies, and ownership costs associated with these decisions.

The Navy seeks development of an intelligent modeling environment, which is agnostic to the source of materials properties data allowing user-definable corrosion materials properties, user-definable corrosion modes/mechanisms, user-definable behavioral relationships between properties & environmental stressors; and provides an integrating platform to connect these corrosion modes/mechanisms to specific materials & geometries read from Computer Aided Design (CAD) data inputs. This would create a corrosion information ecosystem allowing corrosion behavior modes/mechanism relationships to be developed under a technical community crowd-sourcing paradigm, and aid in the development of an integrated Naval corrosion simulation paradigm. The Navy intends to leverage the skills and expertise of a broad base of materials science specialists from academia, industry, and DoD subject matter experts in creating a diverse toolbox of available corrosion simulation engines.

The objective of this SBIR topic is to create an intelligent corrosion tool that can store (and retrieve) a complex dataset along with key materials information and use cases that would trigger selection of specific corrosion simulation engine. The tool would also create an interface to assemble the information from a designer's CAD drawing/modeling environment in order to implement the proper corrosion simulation engine. Specifically, the tool must adequately incorporate modules that accommodate: (1) the materials of interest, derived from CAD packages, (2) the service environment corrosion severity, (3) mechanisms of material corrosion and driving physical parameters for such, and (4) handoff parameters for incorporating these mechanisms into external modeling codes.

Implementing advanced analytics into warship design requires simplifying access to the simulation engines that can perform these analyses. This intelligent tool will have the capacity to read a designer's drawing and extract the key information parameters that may be required to hand over to a corrosion simulation engine. The tool will have capabilities to down select which CAD dimensions, materials, coatings, corrosion countermeasures, etc. are required to evaluate the design against a specific mode of corrosion attack. The tool will also house a cursory analysis module that allows a design engineer to evaluate which modes of corrosion attack are most likely in the specified design, prior to conducting rigorous simulations to determine their severities.

This effort will leverage the Navy-owned materials database as well as materials data or behavioral characteristics to the corrosion database from academia, industries and DoD partners through an interface provided by the developer. The intelligent tool will have clear guidelines on how the data or algorithm must be implemented to be of value to the Navy and provide a means to assess cost avoidance through improved design changes.

Requirements:

- 1) Develop a concept for an Intelligent Corrosion Tool that will develop and demonstrate a computational database architecture that can store and retrieve user-specified material properties and behavior equations for specific materials corrosion modes; and is searchable in context of the material, corrosion mode, corrosivity of the environment, and other user-definable contextual parameters.
- 2) Demonstrate the ability to gather key geometry and materials information from a component drawing file, reading Standard Triangle Language (STL)-based drawings designed in commercial CAD software.
- 3) Allow designation of a “Service Zone” or “Service Environment” based on selecting service parameters from a diagram of a ship/submarine diagram where the component is intended to operate or corrosion severity zone selection. Extract and assemble key information required to exercise corrosion simulation models.
- 4) Demonstrate the ability to read multiple CAD drawings, identify materials and potential corrosion modes, automatically prepare model preprocessing files, and interface files for commercial modeling tools including geometry and modeling parameters.
- 5) Demonstrate the ability to capture cost avoidance data from corrosion countermeasures simulation results.
- 6) Incorporate logic to evaluate drawings/designs against the US Navy’s Corrosion Control and Design Criteria Manual – a wide ranging design document that outlines best practices for robust designs and corrosion cost avoidance.

As part of Phase III, the products will be included in the anticipated Future Naval Capability (FNC) program as a key component that can be utilized by ship designers to enable corrosion-informed materials selection and design.

PHASE I: Develop a concept for a tool that will satisfy requirements 1, 2, and 3 in the Description.

Perform testing and certification using materials properties and drawings supplied by the Navy. Demonstration must include exercising the Intelligent Corrosion Tool against a prototypical working CAD model of a section of the ship’s hull and cathodic protection system to capture corrosion interactions between wetted materials. The Intelligent Corrosion Tool will then return this information to the user in a distilled format. Phase I Option, if exercised, would include the initial layout and capabilities description to build the unit in Phase II.

PHASE II: Based on the results of the Phase I and Phase II Statement of Work (SOW), develop the Intelligent Corrosion Tool that incorporates requirements 4, 5, and 6 in the Description.

Testing and verification for the tool will include analysis of prototypical CAD drawings and comparison against the user-provided materials properties/corrosion modes database. Successful outcomes will involve selecting multiple potential corrosion modes for the materials and geometries included in the CAD drawings, and down select the most likely corrosion mechanism occurrences in the presented scenarios based on the CAD drawings and user-supplied materials database. The tool will then compile the necessary information in order to hand off corrosion mode simulations to commercial/Navy specific analytical packages that are consumers of pre-packaged information provided by the Intelligent Corrosion Tool.

PHASE III DUAL USE APPLICATIONS: Dual Use Applications for the Intelligent Corrosion Tool will naturally evolve from a demonstrated ability to incorporate corrosion cost avoidance into design practices. Engineering design processes for naval warships are similar to engineering design processes for non-military vessels, and many partners that design/build components for the Naval fleet also design/build components for non-military customers, such as automotive, aerospace, oil & gas, and piping industries.

REFERENCES:

1. Taylor, Christopher. "Corrosion Informatics: An Integrated Approach to Modeling Corrosion." Corrosion Engineering, Science and Technology, 2015. <https://doi.org/10.1179/1743278215Y.0000000012>
2. Koch, G., Ayello, F., Sridhar, N., Khare, V., Al-Mathen, A. W., and Safri, S. "Internal Corrosion Threat Assessment of Pipelines Using Bayesian Network Models." Corrosion 2014 Conference, San Antonio, TX; 2014, NACE International. <https://doi.org/10.1179/1743278215Y.0000000005>
3. Anderko, A. "2.38: Modeling of Aqueous Corrosion." Shreir's Corrosion, Elsevier: 2010; pp 1585-1629. <https://downloads.olisystems.com/ResourceLibrary/Corrosion%20review/Shreir%2000083%20-%20Anderko.pdf>
4. Palani, S.; Hack, T.; Deconinck, J. and Lohner, H. "Validation of predictive model for galvanic corrosion under thin electrolyte layers: An application to aluminum 2024-CFRP material combination." Corrosion Science 2014, 78, pp. 89-100. <https://doi.org/10.1016/j.corsci.2013.09.003>

KEYWORDS: Corrosion Model; Corrosion Simulation; Open Framework Architecture; Corrosion Database; Computer Aided Design; CAD Drawing; Corrosion Informed Materials Selection and Design

N211-044

TITLE: Inflatable Deployable Sail Systems for Future Submarines

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop technology that will advance traditional submarine design toward accommodating an Inflatable Deployable Sail System (IDSS) for future submarines.

DESCRIPTION: A submarine designed without a sail would have inherent advantages in submerged operations over a design with a sail in the areas of speed, maneuverability, and acoustic stealth. However, until a solution can be found to safely navigate a submarine without the height of eye and visibility afforded by a sail, no such design can be entertained. Advances in inflatable structures can provide the freeboard needed for surface transit with a temporary and reusable structure. Maturation of this technology will open up the SSN(X) design space to entertain submarines that can operate submerged without the impediments of a sail.

The submarine sail is an integrated structural platform that hosts various Undersea Warfare (USW) systems and equipment including periscopes; communication antenna masts; acoustic, electromagnetic and radar sensor systems; exhaust ports; and crew access/escape trunks. The sail connects the bridge to a secondary (non-pressure) hull that, in turn, connects to the pressure (primary) hull. Crew hatches are positioned at each boundary interface along the sail access/escape trunk. The sail vertically offsets the bridge from the primary hull to provide a specified freeboard. Each submarine class in today's USN Fleet incorporates a fixed rigid sail structure. These traditional sail structures provide a manned bridge that enables the crew to command, communicate and control operations remotely from the internal control room while affording necessary height of eye and on-ship visibility to facilitate surface transits. The sail structure also provides freeboard necessary to enable vertical and underway replenishment (VERTREP and UNREP, respectively) operations without flooding the primary hull.

Sail geometries are optimized for their hydrodynamic performance to minimize flow-induced noise, vibrations and wake effects by using faired leading and trailing edges and, for specific class variants, optional cusp fairings. Unlike the Seawolf, Virginia, and improved Los Angeles class submarines, variants such as the Ohio, original Los Angeles, and Columbia classes incorporate articulating dive planes external to the sail.

The structural loadings, deployment/retrieval operations and stability mechanisms required present significant design and material challenges for an inflatable and deployable sail. NAVSEA's design objectives for future submarines are to explore and innovate sail concepts, including development toward achieving an Inflatable and on-demand Deployable Sail System (IDSS) that is capable of controlled deployment from and stowage inside the secondary hull. The IDSS shall primarily be used for manned bridge operations with a crew access/escape trunk only and will not house the aforementioned USW systems and related equipment.

There are many dimensional and configuration constraints exist for IDSS: The sail dimensions for deployable assembly should have a minimum 16-ft freeboard (other dimensions as necessary for manned bridge capabilities that match current submarine sails); Crew bridge capacity should be at a minimum of 2 crew shoulder-to-shoulder forward of bridge hatch with minimum of 2 crew shoulder-to-shoulder rear of bridge hatch; Bridge and pressure hull hatches should be 30-inch inner diameter; Bridge should have power, lighting and communications (from pressure hull to bridge) and conduits, flip-up windshield, storage lockers, etc.; Crew access/escape trunk (connects pressure hull hatch to bridge hatch), include ladder system; Wave slap should have uniform pressure loading; Bridge weight should be 4,000-lbs maximum; Sail external vertical loads must include weight of ice, etc.; Ice and foreign object impact protection; Ballistic protection (small arms fire); Positive locking stowage configuration.

The minimum operational constraints for IDSS are: Inflatable actuation (potable water, seawater, air/water combination); Operational cycles of 10,000, Deploy/stow at 0.0 knots from periscope depth with cross flow of 5.0 knots; Maintain shape at periscope depth in cross flow velocity of 5 knots; Deploy/stow at surface at vessel speed of 5.0 knots; Deploy/stow during range of sea states (operational to SS6, survivable to SS8); Provide pressure relief for internal pressure exceeding 2.5x ambient pressure within 5.0 seconds; Safety factors for inflatable components: 4.0; Deployment time of 1.0 minute; Stowage time of 1.0 minute; Deflection limits at full deployment shall be 5.0-inches yaw, pitch, roll with respect from bridge to secondary hull (existing fixed sails are stress-limited); and Temperature range of -60°F to 150°F.

The current state of inflatable soft structures technologies can provide unique solutions to the many challenges limiting today's USW operations, capabilities and system designs. Inflatable soft structures have been successfully developed for DoD, NASA, and industry and are generally categorized in the following sectors: Inflatable control surfaces, deployable energy absorbers, and temporary on-demand structures.

Successful design and performance of soft inflatable structures is attributed to technological advancements derived from: High Performance Fibers (HPF) including, but not limited to, Vectran®, DSP® (dimensionally stable polyester), PEN (polyethylene naphthalate), Spectra® (ultra-high molecular weight polyethylene), Kevlar®; Novel fabric architectures and 3-dimensional woven preforms capable of unique mechanical behaviors; Continuous weaving processes for elimination of seams in inflatable structures; Robust Physics-Based Modeling (PBM) methods with Fluid-Structure Interaction (FSI) capabilities including FEA and CFD; and material test methods for characterization of multi-axial and pressure-dependent mechanical behaviors for inputs to numerical models.

Collectively, these advancements have established a sound technology base; one that can be leveraged for innovative solutions to soft structure designs requiring significant load-carrying capacities, shock mitigation, dynamic energy absorption, rapid deployment, large deployed-to-stowed volume ratios, and fail-safe modes of operations.

The Inflatable Deployable Sail Structure (IDSS) shall consist of a generally soft or soft/rigid hybrid inflatable structure with a rigid or hybrid rigid/inflatable bridge. The IDSS will connect to the submarine's seawater pump interface (SPI) and air flask interface (AFI). The tube seawater pump and air flask shall be used to control inflation and deflation of the IDSS with seawater and air as the possible inflation media.

The soft structures considered for use in developing the IDSS may include, but are not limited to, control volumes constructed of inflated membranes, 3-D woven preforms, flexible bladders, coated fabrics, and hybrid (soft/rigid) material systems, and hard goods-to-soft goods connections. Hybrid inflatables may

include inflatable elements with semi- or fully-rigid reinforcements serving as deployment shaping controls, and abrasion resistant contact surfaces. The pressurization media for all inflatable components will be limited to seawater and air.

Structural testing of the IDSS concept shall be required to validate the operational performance and resistance to wave slap loading using a full-scale IDSS prototype and in accordance with stated objectives using air, water, or both as the inflation media. The tests shall demonstrate:

Test-1: deployment from the stowed to the fully deployed (operational) configuration.

Test-2: resistance to wave slap and impact loadings along the port and starboard athwart ship directions and the fore and aft longitudinal directions when fully deployed.

Test-3: retrieval from the fully deployed configuration to the stowed configuration.

The company shall identify recognized issues and propose resolutions affecting operational performance and reliability, crew and system safety, environmental exposure effects (temperature, cyclic fatigue, UV, abrasion, puncture, impact, biofouling, chemical/biological, etc.) and maintenance concerns including crew accessibility and repair methods. Failure modes effects analyses (FMEA) shall be performed for the primary structural and inflatable components.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Create a virtual design concept for an IDSS including a Concept Feasibility Analysis (CFA). The CFA shall assess the IDSS concept using Finite Element Analysis (FEA) to characterize the structural response and stability for hydrostatic, hydrodynamic, wave slap, ice and foreign object impact loading events. Additionally, Computational Fluid Dynamics (CFD) modeling shall analyze the hydrodynamic and flow noise/vibrations responses. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build and test a prototype solution in Phase II.

PHASE II: Optimize the IDSS design based on the results of the Phase I and Phase II Statement of Work (SOW) including material selections for the soft structural components, pneumatic/hydraulic layout design and manifolding, inflation/deflation sequencing, porting to the submarine's seawater interface pump and air supply flask, hard-to-soft-goods connections, power, data and lighting connections to the pressure hull, environmental factors. Identify and document all operational, safety, environmental and maintenance issues as recognized during development of the proposed IDSS design. Perform risk identifications, risk assessments, and risk mitigation plans from the concept development stage.

Build a full-scale structural prototype of the proposed IDSS and test to validate the above requirements. Correlate the results of models developed to those obtained from the prototype tests, including deflections, reaction forces and the pressure-time histories for each inflated component and loading direction.

Deliver the prototype IDSS to the NAVSEA designated Warfare Center(s) for testing in accordance with the stated operational requirements.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: The technologies are applicable to future underwater weapons, Unmanned Underwater Vehicles (UUVs), Unmanned Surface Vehicles (USVs), and commercial/industrial dual use. All technologies including designs, material data, manufacturing methods, prototype test results, etc. developed under this topic shall be transferred to the Navy for transition to future submarines, UUVs, USVs and underwater weapons. Potential commercial applications include adaptable and deployable structures for the construction industry, Lighter-Than-Air (LTA) ships, space vehicle structures (including deployable control surfaces) and habitats, civil infrastructure protective systems (land, air and port barriers; levee sealing and erosion repair), chemical/biological containment systems for internal use aboard aircraft and mass transit ground vehicles, blast/shock mitigation and impact energy absorption devices), and maritime safety systems (rescue and buoyant recovery platforms).

REFERENCES:

1. Burcher, R. and Rydill, L. "Concepts in Submarine Design." Cambridge Ocean Technology Series, Cambridge University Press, 1994. <https://www.amazon.com/Concepts-Submarine-Design-Cambridge-Technology/dp/052155926X>
2. Hulton, A., Cavallaro, P. and Hart, C. "Modal Analysis and Experimental Testing of Air-Inflated Drop-Stitch Fabric Structures used in Marine Applications." 2017 ASME International Mechanical Engineering Congress and Exposition, IMECE2017-72097, Tampa, FL, November 3-9, 2017. <https://asmedigitalcollection.asme.org/IMECE/proceedings-abstract/IMECE2017/58448/V009T12A030/261952>
3. Cavallaro, P., Hart, C. and Sadegh, A. "Mechanics of Air-Inflated Drop-Stitch Fabric Panels Subject to Bending Loads." NUWC-NPT Technical Report #12,141, 15 August 2013. https://www.researchgate.net/publication/267596423_Mechanics_of_Air-Inflated_Drop-Stitch_Fabric_Panels_Subject_to_Bending_Loads
4. Cavallaro, P., Sadegh, A. and Quigley, C. "Contributions of Strain Energy and PV-Work on the Bending Behavior of Uncoated Plain-Woven Fabric Air Beams." Journal of Engineered Fibers and Fabrics, vol. 2, 2007, pp. 16-30. <https://www.jeffjournal.org/papers/Volume2/Sadegh.pdf>
5. Cavallaro, P. and Sadegh, A. "Air-Inflated Fabric Structures, Marks' Standard Handbook for Mechanical Engineers." McGraw-Hill, 11th Edition, 2006, pp. 20.108-20.118. https://www.researchgate.net/publication/235213999_Air-Inflated_Fabric_Structures

KEYWORDS: Submarines; Submarine Sail Structures; Soft Structures; Inflatable Structures; Fabric Structures; Technical Textiles; Inflatable Deployable Sail Structure; Deployable Submarine Bridge; IDSS

N211-045

TITLE: Extended Life and Low Maintenance Aircraft Tie Down Fitting

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop an extended life, low maintenance, affordable aircraft deck tie down fitting for aircraft carrier applications.

DESCRIPTION: Aircraft securing fittings (commonly refer to as “deck tie-down fittings”) as part of flight deck provides an attachment point for onboard aircrafts (i.e., fighter jets, auxiliary planes, helicopters) to prevent movement of aircraft, equipment, or materials due to ship movement and wind. It is essential that the aircraft and equipment be secured in a manner to prevent motion in all directions aboard the ship. Depending on the sea state and weather condition, on average 4 to 12 deck tie-down securing points are used for securing an aircraft. A typical configuration of a deck tie down fitting assembly consists of a crossbar welded onto a fitting cup, which is typically manufactured from heat treatable low alloy steel, and welded onto the flight deck. In aircraft carrier applications, a five-crossbar type tie down fitting is welded directly onto a deck, which is the application of focus under this SBIR topic.

For corrosion protection from marine environment, a coating of military specification grade polyamide epoxy primer is applied on both the crossbar and fitting/deck, post installation; however, due to a constricted access point for paint application and exposure to heavy abrasion during service, the coating is prone to damage. As a result, the corrosion and abrasion of the steel flight deck tie down assembly, especially on the crossbar, has been a persistent issue, leading to severe degradation on ship readiness and increased maintenance burden. A more durable flight deck tie-down fitting needs to be developed for the aircraft carrier application. Durability of the new flight deck tie down fitting must be able to withstand the corrosive marine environment, abrasion and impact from the securing hook and support a significant reduction in maintenance requirements than the current version of the deck tie down fittings to reduce the maintenance burden. The new flight deck tie down fitting must be affordable to support a reduction in total ownership cost during its life cycle. The affordability needs to be addressed both on the material and labor cost front, for the overall economic feasibility.

There are several types of Navy-approved aircraft secure tie down fittings conforming to NAVSEA Drawing 803-1916300 (Hull Standard Drawing Aircraft Securing and Engine Run-Up Fittings). On aircraft carriers, five crossbar fitting Type VIII is installed for providing an additional pull strength for securing aircrafts and equipment aboard the carrier. Type VIII tie down fittings are welded onto the deck, instead of welding onto a fitting cup as previously mentioned. Dimensions and requirements data for deck tie down fittings are covered under the referenced NAVSEA drawing. This NAVSEA drawing is not available on internet on public domain; however, a commercial version of this specific tie down fitting is available through a commercial vendor and their relevant design information [Ref 1]. It is noted that the referenced NAVSEA drawing (803-1916300) supersedes any existing discrepancy on dimensions and design requirements between the two drawings. Replacement of a failed or degraded secure fitting is a significant driver for cost and maintenance burden due to the high number of flight deck tie down fittings installed and the required replacement rate of several hundred tie down fittings for supporting mission operation and readiness.

The Navy is seeking a more durable (e.g., fabricated from a material that is more resistant to corrosion and abrasion than current steel when exposed to seawater and marine environment) deck tie down fitting that would support a form, fit, function replacement of the legacy steel tie down fittings (five crossbar Type VIII version only) on aircraft carriers. This also includes replacement of the two deck lugs installed

between the two crossbars for each tie down fitting installed on landing areas of the flight deck with the same corrosion resistance and durable lugs.

The Navy requires tie down fittings that have similar strength as the current fittings (4130 grade steel), are also resistant to corrosion, and wear for a minimum service life of 25 years or more with desirable target of 50 years for supporting entire life cycle of an aircraft carrier. While in service, 100% of the tie down fittings are inspected with a go/no-go gauge per Navy maintenance inspection procedure. The go/no-go gauge is intended to inspect for a reduction in thickness of the crossbar below the required minimum level due to degradation from corrosion and wear/tear while in service.

Dimensions: For this SBIR topic, the only applicable flight deck tie down fitting is five crossbar Type VIII, which is the most common type installed on aircraft carriers. The commercial equivalent of Type VIII and the relevant design parameter is available for access and view online through the commercial vendor's website. Due to limitation of flight deck configuration, increase or scaling up of the tie down fitting design cannot be supported and will not be considered as a potential solution.

Load: Refer to the flight deck tie down fitting pull test requirements in System Requirements section above.

Shock: N/A as flight deck tie down fitting is considered as a part of the overall ship structure and not subjected to a separate shock requirement.

Vibration: N/A as flight deck tie down fitting is considered as a part of the overall ship structure and not subjected to a separate vibration requirement.

Welding: Cross member material must be compatible to be welded/joined to high strength steel and minimal heat control processing to support in service replacement. In order to meet the minimum heat control-processing requirement, material selection consideration must include a base material/filler metal not subject to heat-affected zone hardenability and hydrogen cracking. Final weld to meet nondestructive testing, such as visual and dye penetrant inspection to acceptance standards, and load testing are requirements for a successful tie down fitting. Minimum requirements for the fabrication and welding design for ship structures are covered in MIL-STD-1689 and provides general welding and inspection requirements for the tie down fittings.

PHASE I: Develop a concept for a corrosion resistant and durable aircraft deck tie down fittings for aircraft carrier application. Describe how the technology will be implemented, provides cost ranges for the systems, and provides notional shipboard implementation. Conduct both literature review and testing of material properties to meet various Navy requirements. (Note: Navy can provide guidance document to selected performers.) Establish feasibility by material testing and/or through analytical modeling. Phase I Option, if exercised, should include the initial specifications and capabilities for the technology to be developed in Phase II.

PHASE II: Produce 15 prototype aircraft securing fittings for delivery and evaluation to determine its capability in meeting the performance goals defined in the Phase II SOW and the Navy requirements specified under NAVSEA Drawing 803-1916300 (Hull Standard Drawing Aircraft Securing and Engine Run-Up Fittings). Ensure that the prototype material can be welded to high strength steel with qualified welding procedures in accordance with the appropriate Navy specific requirements for welding on high strength material. Demonstrate performance through prototype evaluation and testing over the required range of parameters (i.e., accelerated corrosion, wear, weld-ability, and mechanical properties) including numerous deployment cycles to verify test results. For mechanical properties, ensure that the fitting satisfies the pull strength requirement specified in the NAVSEA Drawing 803-1916300 applicable to

Type VIII tie down. Using the evaluation results, refine the prototype into an initial design that will meet Navy requirements. Prepare a Phase III development plan to transition the technology for Navy use.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Navy use. Support the Navy for test and validation to certify and qualify the system for Navy use. The technology must be transitioned to the aircraft carrier platform.

This technology may also reduce maintenance and operations costs for commercial ships and aviation. Government and commercial space programs may also benefit from adopting the technology.

REFERENCES:

1. Tie down Fitting Part Number: PH285P-8, Peck & Hale LLC Product Page.
<https://www.peckhale.com/products/ph285p-8>
2. MIL-STD-1689 Rev A, (1990).
https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=37098
3. N211-045-Reference_Document_803-1916300-REV-P https://navysbir.com/n211/Topic-N211-045-Reference_Document_803-1916300-REV-P.pdf

KEYWORDS: Aircraft Secure Fittings; Aircraft Deck Tie Down Fittings; Flight Deck Tie Downs; Tie Downs; Corrosion Resistant Tie Downs; Five Crossbar Type VIII Tie Down Fitting

N211-046 TITLE: Undersea Warfare Decision Support System Coalition Data Parser & Advanced Display

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an automated coalition data parsing and 4D display application that enables coalition interoperability for Theater Undersea Warfare (TUSW).

DESCRIPTION: The Undersea Warfare Decision Support System (USW-DSS) is an Anti-Submarine Warfare (ASW) command and control (C2) system installed aboard United States Navy (USN) carrier strike group (CSG) platforms (CVN, CGs/DDGs); Surveillance Towed Array Systems (SURTASS) ships; embarked Destroyer Squadron Staffs and select shore nodes to include the Naval Oceanographic Processing Facilities (NOPF); and Commander Task Force (CTF)/Theater USW Operations Centers (TUSWOC) that enable the networking of ASW forces to collaboratively plan and execute ASW missions. USW-DSS uses both live data and constructed or simulated data to create a live, virtual, and constructive (LVC) modeling and simulation (M&S) capability for Theater ASW planning and analysis of mission execution.

USW-DSS contains applications for environmental analysis, collaborative search planning, force management, sharing of a common tactical picture with networked tactical decision aids, sensor tracks and sensor metrics, automated and manual cross-platform track fusion, search execution measures of effectiveness, graphics storage, recall, and ASW briefing support. The applications also improve effectiveness by decreasing the time required to search an area to a desired probability of detection.

Currently, a universal data adapter for deployed systems is not commercially available; However, there is a similar solution in the training and M&S communities. It is IEEE Distributed Interactive Simulation (DIS). DIS is commonly used as a standard for conducting real-time platform level war-gaming. In order to participate in LVC event, a data adapter is usually developed to bridge the communication between platforms.

The Navy seeks a solution for an automated coalition data parser and 4D display application that may be shared with foreign partners. The data to be exchanged include environmental information (such as local sound speed profiles, ambient noise measurements), data that informs search planning and force management (such as ship speed and maneuvering characteristics, fuel availability and consumption, ASW sensor health and system capabilities), data to generate common tactical pictures, output from tactical decision aids, tracked contacts, search execution measures of effectiveness, and graphics required to generate ASW briefing materials. Additional data and format of existing systems will be provided during Phase II.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for a coalition data parser and 4D display application. Demonstrate the concept can feasibly meet the requirements in the Description through modeling and analysis. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype of the coalition data parser and 4D display application. Provide to USW-DSS subject matter experts for testing and verification at a government-provided facility. Demonstrate the prototype performance through the required range of parameters given in the Description.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use in an integrated element of USW-DSS through system integration and qualification testing. The coalition data parsing and display adaptation capability will be delivered to support a single transition event. Integrate the prototype into a future build of USW-DSS.

The coalition data parsing and display application can be adapted to other technical fields requiring complex systems to straddle disparate systems with similar data, including systems for engineering and medical uses. The ability to readily adapt to similar but disparate systems with displays that optimize utility by users of all the disparate systems would also be useful in the education and business community.

REFERENCES:

1. "AN/UYQ-100 Undersea Warfare Decision Support System (USW-DSS)." United States Navy Fact File. https://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=324&ct=2
2. 1278.1-2012 IEEE Standard for Distributed Interactive Simulation -- Application Protocols. Institute of Electrical and Electronics Engineers. <https://ieeexplore.ieee.org/document/6387564/>; <https://www.worldcat.org/title/12781-2012-ieee-standard-for-distributed-interactive-simulation-application-protocols/oclc/958630947>
3. Gilman, George H. "A Reusable Simulation Environment for Digital Engineering." MODSIM World 2019. http://www.modsimworld.org/papers/2019/MODSIM_2019_paper_4.pdf

KEYWORDS: Theater Undersea Warfare; Undersea Warfare Decision Support System; Distributed Interactive Simulation; Live, Virtual, and Constructive; LVC; M&S; Modeling & Simulation

N211-047 TITLE: Unmanned Underwater-Vehicle (UUV) Mission Sensitive Energy Usage Optimization Using Automated Intelligent Services

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop decision-making algorithms and planning software that can recommend UUV mission plans satisfying operator-defined mission goals and priorities by proposing joint UUV-path plans and sensor-usage schedules that optimize the UUV's energy-usage efficiency over an entire mission.

DESCRIPTION: Unmanned Underwater Vehicles (UUVs) are energy-constrained platforms that execute complex missions in dynamic, and often unpredictable, environments. The advent of advanced sensing payloads and the Navy's interest to extend the operational lifetime of UUVs demand advanced, dynamic, UUV mission-planning tools that go beyond path-planning optimization and "static" mission objectives alone. In particular, there is a need to optimize UUV mission plans based on prioritized objectives with respect to path plans, sensor usage, and energy consumption while ensuring that prioritized mission objectives continue to be satisfied. Most UUV mission planning tools available today rely on models that quantify sensor coverage and energy consumption to define a 'static' mission plan prior to starting the mission. These plans often predefine the power budget for the UUV and its payloads, and guarantee an ample energy reserve for UUV emergency procedures. Missions are, however, dynamic in nature and the corresponding mission plans should be reevaluated and optimized on-board the UUV during mission execution.

The Navy is looking for mission-effectiveness optimization algorithms that leverage classical control, optimization techniques, and modern artificial intelligence and machine learning methods to develop software tools able to dynamically recommend UUV routes and sensor-usage schedules. The proposed energy usage schedule must account for the UUV's energy usage over the entire mission and dynamically adjust the schedule according to the mission requirements. The proposed algorithms must also define clear mission-objective satisfaction metrics for assessing mission effectiveness as a function of the mission priorities, the sensor-payload activation schedule, and the overall energy consumption of the UUV. The software implementation of these algorithms should provide the initial mission plan (i.e., route, and sensor operating modes and activation schedules); support on-board monitoring of the UUV's energy usage across the navigation and sensor payloads; evaluate the path and schedule effectiveness with respect to mission objectives of the sensor payload activations along the planned UUV route in real-time on-board the UUV; and dynamically recommend changes to the current mission plan to maximize mission effectiveness. It is critical that any decision-making approach executed on-board the UUV in response to the dynamics of the mission and the environment to redefine the mission plan can be executed efficiently and within predefined computational and power-usage constraints demarcated by the UUV's internal configuration.

To ensure interoperability with the PMS 406 portfolio, the software solution must comply with the Unmanned Maritime Autonomy Architecture (UMAA). UMAA establishes a standard for common interfaces and software reuse among the mission autonomy and the various vehicle controllers, payloads, and Command and Control (C2) services in the PMS 406 portfolio of Unmanned Systems (UxS) vehicles. The UMAA common standard for Interface Control Documents (ICDs) mitigates the risk of vendor lock from proprietary autonomy solutions; effects cross-domain interoperability of UxS vehicles; and allows for open architecture (OA) modularity of autonomy solutions, control systems, C2, and payloads. The Navy will provide the open standards for UMAA upon award of Phase I.

Work produced in Phase II may require access to classified information and become classified. Note that the prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected contractor will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a software-system concept with dynamically reconfigurable routing and sensor-usage schedule algorithms to maximize UUV mission effectiveness by making efficient use of the available energy. Quantify expected energy-usage efficiency improvements and their impact on UUV mission execution, e.g., duration and increased sensor duty cycles, and vehicle configuration, e.g., reduced battery size. Conduct simulations using realistic scenarios and surrogate UUV autonomous control systems to demonstrate and quantify mission effectiveness improvements to demonstrate feasibility of the concept. The software products completed during this phase should be sufficient to demonstrate the implementation feasibility of algorithms, with corresponding software modules interfaced with surrogate UUV autonomous control systems that optimize planning, execution, and energy usage on UUVs to achieve maximum mission effectiveness. The Phase I Option, if exercised, would include the initial layout and capabilities description to build the unit in Phase II. Notional computational and power-usage constraints for select classes of UUVs will be identified in this Phase by the performer in collaboration with PMS 406.

PHASE II: Prior to starting prototype development, performers must identify and discuss with PMS406 the following items: (i) target UUV, access requirements and availability; (ii) UUV autonomy framework and required documentation; (iii) computational and power-usage constraints applied to the targeted UUV (leveraging Phase I analysis); and, (iv) approach for accessing the UUV and all related information needed. Develop a full-scale system prototype that can generate initial mission plans that maximize mission effectiveness and dynamically quantify their effectiveness in realistic mine countermeasure (MCM) scenarios (both real world and simulated). Conduct test and evaluation of the system prototype to quantify UUV-mission-effectiveness improvements. Demonstrate the feasibility of integrating the prototype system with one or more UUV autonomy systems using either a real UUV or a high-fidelity software-in-the-loop (SITL) simulation. Conduct extensive test and evaluation to quantify the UUV mission effectiveness improvements from dynamic mission optimization in realistic MCM mission scenarios with successful demonstration showing that the software can be used on-board a UUV to maximize mission effectiveness without significantly overburdening the computational resources available within the UUV.

It is possible that portions of the work under this effort could be classified under Phase II or Phase III (see Description Section).

PHASE III DUAL USE APPLICATIONS: To ensure interoperability with the PMS 406 portfolio, refine the system solution to comply with the UMAA. Ensure that the system provides a UMAA-compliant software service that provides joint path-planning and energy-usage optimization services by dynamically defining UUV routes and payload activation schedules; and that the resulting service interfaces with UUV autonomous control systems and supports the development of mission plans that maximize mission effectiveness. The target transition platform for the software solution developed as part of this SBIR topic is the Razorback UUV. Inspection, maintenance and repair (IMR) missions for undersea infrastructure,

and ocean-bottom mapping and exploration are dual-use applications where the UUV technology developed as part of this SBIR topic will have commercial impact.

REFERENCES:

1. Thibbotuwawa, A., Nielsen, P., Zbigniew, B. and Bocewicz, Grzegorz. "Energy Consumption in Unmanned Aerial Vehicles: A Review of Energy Consumption Models and Their Relation to the UAV Routing." Proc. of 39th International Conference on Information Systems Architecture and Technology, Nysa, Poland, Sept. 16-18, 2018. https://link.springer.com/chapter/10.1007/978-3-319-99996-8_16
2. "Unmanned Undersea Vehicles." RAND National Defense Research Institute. <https://www.rand.org/pubs/monographs/MG808.html>
3. Ewachiw, Mark A., Jr. "Design of an Autonomous Underwater Vehicle (AUV) Charging System for Underway, Underwater Recharging." MS Thesis, 2014. Massachusetts Institute of Technology. Cambridge, MA. <https://calhoun.nps.edu/bitstream/handle/10945/43069/Ewachiw%20%282014%29%20-%20CIVINS%20MIT%20Thesis.pdf?sequence=1&isAllowed=y>
4. Yang, N., Chang, D., Amini, M.R., Johnson-Roberson, M. and Sun, J. "Energy Management for Autonomous Underwater Vehicles using Economic Model Predictive Control." 2019 American Control Conference (ACC), Philadelphia, PA, USA, pp. 2639-2644. <https://arxiv.org/pdf/1906.08719>
5. Woithe, H.C. and Kremer, U. "Feature based adaptive energy management of sensors on autonomous underwater vehicles." Ocean Engineering, vol. 97, 2015, pp. 21-29. <https://www.sciencedirect.com/science/article/abs/pii/S0029801814004272>

KEYWORDS: Algorithms and Software for UUVs; A&S; Mission Planning and Execution for UUVs; Dynamic Mission Planning; Energy Usage Optimization for UUVs; Unmanned Underwater Vehicle; UUV; MCM Operations

N211-048

TITLE: Unified Operational Picture for Anti-Submarine Warfare

RT&L FOCUS AREA(S): Machine Learning/AI

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a fused picture from acoustic and non-acoustic sensors that transforms masses of data into concise, useful information for operators, watch team, and decision makers.

DESCRIPTION: Undersea warfare (USW) presents a uniquely complex environment to the human operator involving phenomena not present in environments commercial products focus on. Current systems rely heavily on manual association of contact information across sensors. This can be challenging in cluttered environments. Sensor improvements (resulting in more arrays, more gain, more beams, etc.) compound the problem, which can in turn lead to a degradation in situational awareness, incorrect contact picture, and possibly loss of tactical control.

The variable nature of the ocean floor, changing currents, unpredictable water temperature and density layers, marine life, and a huge spectrum of vessel traffic create a highly complex tactical picture in which an adversary can hide. Multiple specialized and highly sensitive sensors have been deployed over the years to contend with these conditions and fully penetrate the undersea battlespace. However, under stressing conditions and, taken collectively, the array of sensors employed by the undersea warfighter yields a copious flow of data and information that must be rapidly analyzed and interpreted. A multi-sensor fusion technology is needed to generate a unified and consistent tactical picture. The solution must be capable of analyzing, assimilating, and fusing data in an approach that considers both coherent and incoherent processing across multiple sensors with utilization of kinematic and spectral information in order to generate a single, unified, decision-quality, tactical picture.

While the technology sought under this topic will need to comply with cybersecurity protocols, cybersecurity, per se, is not necessarily required as an embedded aspect of the solution provided. While ideally fusion would involve multiple sensors having simultaneous contact, there will be times when only one sensor has contact. The fusion desired is an overarching awareness of contacts as they are perceived by different sensors and modes, both when there is temporal overlap and when there is not temporal overlap.

During Phase II, the technology will be evaluated by Navy subject matter experts and Fleet operators in a prototype sonar system using at-sea test data for validation. It may also be evaluated in an unmanned operation if appropriate for the solution.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected

contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for the unified tactical picture that meets the requirements in the Description section. Feasibility will be demonstrated through analytical modeling, and developing and documenting the innovative algorithms, concepts, and architectures, and quantifying achievable performance gains. The Phase I Option, if exercised, will include the initial system specifications and a capabilities description to build a prototype in Phase II.

PHASE II: Develop and deliver the concept for the unified tactical picture into a prototype. The prototype will be evaluated by Navy subject matter experts and Fleet operators in a prototype sonar system using at-sea test data to validate that it is fit for use. Conduct additional laboratory testing, modeling, or analytical methods as appropriate depending on the company's proposed approach.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through system integration and qualification testing for the unified tactical picture prototype developed in Phase II. Assist in transition and integration of the prototype to a future Advanced Capabilities Build (ACB) update to the AN/SQQ-89A(V)15 Combat System. Potentially integrate the technology into other sonar systems and military sensor systems.

Additionally, the technology could be of interest to intelligence, military, law enforcement, or market tracking for situations where a unified view needs to be assembled from a diverse set of sensor measurements or real-time situational awareness must be assembled in dynamic or volatile situations.

REFERENCES:

1. Moacdieh, Nadine Marie and Sarter, Nadine. "The Effects of Data Density, Display Organization, and Stress on Search Performance: An Eye Tracking Study of Clutter." IEEE Transactions on Human-Machine Systems 47, December 2017, pp. 886-895.
<https://ieeexplore.ieee.org/document/7971994>. Libraries holding this document can be found at https://www.worldcat.org/title/the-effects-of-data-density-display-organization-and-stress-on-search-performance-an-eye-tracking-study-of-clutter/oclc/7252229922&referer=brief_results
2. Agrawal, Rashmi. "Technologies for Handling Big Data." Handbook of Research on Big Data Clustering and Machine Learning, IGI Global, October, 2019.
https://www.worldcat.org/title/technologies-for-handling-big-data/oclc/8303222462&referer=brief_results
3. United States Navy Fact File: AN/SQQ-89(V) Undersea Warfare / Anti-Submarine Warfare Combat System. https://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=318&ct=2

KEYWORDS: Multi-sensor; Fusion of tactical sensors; Tactical Picture; coherent processing; incoherent processing; kinematic information.

N211-049

TITLE: High Power MegaWatt (MW) Class Grating for High Energy Laser (HEL) System

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a new high peak power broad bandwidth efficient diffraction grating for MegaWatt (MW) class continuous wavelength (CW) and ultrashort pulse laser (USP) technology.

DESCRIPTION: High efficiency Volume Bragg Gratings (VBGs) in photo-thermo-refractive (PTR) glass provide unmatched optical filtering capabilities with optical densities as high as 50 dB and linewidths as narrow as 1 cm-1. In this area, the Navy has reviewed recent advances in VBG technologies that enabled key improvements of high efficiency grating properties and led to development of unique VBG-based optical filters for RAMAN spectroscopy and other applications. Currently commercial VBG operates with laser beams that have only narrow band (< 1 nm) linewidth for spectral beam combination. At present narrow linewidth (< 1 nm) KW class CW laser are very expensive. Broad linewidths around 5 nm are more stable and cost-effective. Spectral beam combination (SBC) using current VBG is limited to its operating at spectral range. The proposed broadband VBG can combine multi wavelengths within 200nm bandwidth and has the potential to increase power > MW in a very cost-effective approach to fabricate high-energy laser (HEL) for navy battle space supremacy. The proposed broadband grating (> 200 nm) shall be able to increase laser power greater than MW class using spectral beam combination and shall also have high damage threshold to compress the high peak power (> GW) femtosecond laser.

VBGs in photo-thermo-reflective (PTR) glass has been used for various applications, such as longitudinal and transverse mode selection in diode, solid-state laser resonators, stretchers and compressors for picosecond and femtosecond lasers, and mirrors for high brightness dense spectral beam combining angular beam deflectors/magnifiers. Theoretical and experimental studies of VBGs, their properties and the possibility to make much thicker VBGs in PTR glass compared to polymer-based materials or thin oxide and semiconductor films allow for fabrication of optical filters with linewidths orders of magnitude narrower than those by other techniques.

Volume Bragg Gratings (VBGs) have become an essential component of high-power laser technologies by allowing SBC, stretching and compression of ultrashort laser pulses, frequency stabilization, etc. An innovative compact efficient VBG technology has potential applications due to its high efficiency and high-power laser-radiation damage threshold. However, their high efficiency is limited to a narrow spectral bandwidth, and is typically accompanied by a narrow angular bandwidth.

The Navy seeks an innovative compact, efficient high-power Volume Bragg Grating (VBG) that could exhibit near 99% optical efficiency in broad bands of spectrum (> 200 nm) at 1 to 2 μm optical wavelength. Of particular interest are infrared operation wavelength with a broad spectral range of angles, which can be inexpensively manufactured (i.e., using affordable standard optical material processing

equipment's and affordability that does not required any special manufacturing process and equipment) in sizes exceeding 200mm. The technology has to offer the versatility of controlling the spectral bandwidth of diffraction for adaptation to specific application needs. Emerging grating technologies such as diffractive wave plates and metamaterials appear promising for the technology objectives. The Navy seeks the inclusion of recent advances in VBG technologies or any new innovation that shall meet the proposed volume of around 4 inch³, and ease of manufacturing that enable fabrication of very high efficiency (> 90%) reflecting gratings with broad linewidth >200nm at 1 to 2 μ m wavelength.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been be implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for an innovative, spectral and angular broadband, high diffraction efficiency grating technology that will support ultrafast lasers for pico second/femto second pulse compressor for > 10 mJ pulses at kHz repetition rate or spectral beam combining MW class high energy laser (HEL). Demonstrate the feasibility of the technology for scaling to large area. Through modeling and simulation, demonstrate the feasibility for combining spectrally broadband laser beams > 200 nm. The Phase I Option, if exercised, will include a proposed design that will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop the required technology and incorporate it into a prototype device for high power CW laser Spectral beam combining (SBC) and for ultrafast lasers CPA beam compression technology. Demonstrate that the technology meets the requirements as described. Perform SBC and high power testing for beam combination, and peak power pulse compression to generate GW class of pulse femtosecond laser. Follow on testing will refine the prototype into technology for operational use. Deliver the prototype diffraction grating for the purpose of femtosecond pulse compression or SBC of MW class laser system. Deliver the prototype VBG for -MW class CW HEL SBC and femtosecond laser > 10 mJ per pulse beam compression and evaluation of its power and EO efficiency in a HEL prototype system that can meet Navy performance goals (> 200 nm spectral bandwidth) by the US Navy.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Assist the Navy to transition the Phase II prototype of the high power compact efficient broad linewidth VBG to Navy use for the purpose of HEL technology integration at 1 to 2 μ m MW class laser. Assist in the integration of the laser system into a submarine or other Navy platform to advance the future Navy warfighting capability. Transition this technology into commercial markets, such as automobile and aircraft industries that employ very high power lasers for cutting, drilling, and welding applications.

REFERENCES:

1. Jelger, P., Pasiskevicius, V. and Laurell, F. "Narrow linewidth high output-coupling dual VBG-locked Yb-doped fiber laser." Opt. Express 18, 4980-4985 (2010).
<https://doi.org/10.1364/OE.18.004980>

2. Wang, F., Shen, D., Fan, D. and Lu, Q. "Spectrum narrowing of high power Tm: fiber laser using a volume Bragg grating," Opt. Express 18, 2010, pp. 8937-8941.
<https://doi.org/10.1364/OE.18.008937>
3. Tabiryan, N., Roberts, D., Steeves, D. and B. Kimball. "4G Optics: New Technology Extends Limits to the Extremes." Photonics Spectra, March 2017, pp. 46-50.
https://www.researchgate.net/publication/327232834_New_4G_optics_technology_extends_limits_to_the_extremes
4. Tabiryan, N., Cipparronne, G. and Bunning, T.J. "Diffractive waveplates: introduction." JOSA B 36 (5), DW1-DW2, 2019 (Special Feature Issue). <https://doi.org/10.1364/JOSAB.36.000DW1>
5. Tabiryan, N.V., Nersisyan, S.R., Steeves, D.M. and Kimball, B.R. "The Promise of Diffractive Waveplates." Optics and Photonics News, 21 (3), 2010, pp. 41-45.
<https://doi.org/10.1364/OPN.21.3.000040>

KEYWORDS: Spectral beam combination; SBC); picosecond pulse; ps; femto second laser; Volume Bragg Gratings; VBG;

N211-050 TITLE: Electronic Warfare System Alert Monitoring, Prioritization, and Display

RT&L FOCUS AREA(S): Machine Learning/AI

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop algorithms and visual display elements to ingest, analyze, prioritize, display, and monitor electronic warfare system alerts that optimize human operator performance and combat efficiency.

DESCRIPTION: The Navy's surface electronic warfare (EW) systems are receiving a series of complete technology upgrades under a phased development and acquisition approach that delivers new capabilities (system hardware) to the Fleet in "block" updates. This includes the introduction of new electronic support (ES), electronic attack (EA), countermeasures (CM), and electro-optic and infrared (EO/IR) systems. Taken collectively, these updates result in a completely new, fully modernized, and greatly expanded Surface Fleet EW capability. However, the increased levels of performance and enhanced mission capabilities being deployed by these hardware improvements are accompanied by an increased burden on the EW operator. The EW operator now has access to more ES information of a greater depth than ever before. As sensor data from radar, EO sensors, and even other ships are fused with the expanded ES data available, the burden on the operator increases exponentially. Operator overload and fatigue are serious problems. While some of this data can be processed automatically by using machine learning or adaptive algorithms, the Navy cannot remove the operator entirely from the loop and the EW operator and display will remain a critical element in surface combat.

Of particular importance, the EW operator receives a continuous stream of alerts detailing target contacts, system performance, and mission status. Add to these external cues, commands, and situational updates and the volume of alerts can rapidly become unmanageable, especially during highly dynamic operations in dense signal environments. These alerts are important to maintaining successful operations; however, not every alert is of equal importance. Operation during stressing engagements demands that the operator recognize and parse the most important information in real time and in parallel with a large amount of other information presented on the display. While this problem is currently revealing itself in EW operations, the same situation will no doubt present itself in other display consoles as other legacy weapon systems are upgraded and new weapon systems (such as directed energy weapons) are introduced to the Fleet. There are no current commercial applications that can meet this need.

The Navy requires an alert messaging management and display technology that ingests, analyzes, prioritizes, organizes, monitors, displays, and tracks alert information presented on the EW operator display. The solution should incorporate a coherent methodology, realized in an architecture of algorithms, and demonstrated on representative displays. Tactical software is not expected from this effort. The solution must be modular and extensible to allow deployment to other display consoles (for example, future directed energy weapons displays) and the solution must be compatible with other elements of the display – for example, processing and display of the alerts must not alter, overwrite, or

obscure other elements presented on the display nor should it inhibit other display functions. Since actual tactical displays will not be available, the prototype solution should be demonstrated, tested, and validated on representative display mock-ups.

This effort expects the application of the current state of the art in human cognitive science. The solution should be dynamic to adjust to changing situations that demand re-prioritization of alerts. However, clarity of the display is paramount and the operator cannot be expected to search for constantly changing information. The solution should also include an analysis function that prioritizes and organizes alerts in light of current mission requirements and the evolving battlespace. Finally, the solution should monitor, track, and capture the operator response, elevating alerts and enhancing visual cues in order to make sure the most important alerts are addressed and not overlooked. Compatibility with embedded training events during which scripted alerts are injected into the system is required.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Propose a concept for an EW alert analysis, prioritization, and monitoring application that meets the objectives stated in the Description. Feasibility shall be demonstrated by a combination of analysis, modelling, and simulation. The feasibility analysis shall include predictions of operator performance in use of the application. The Phase I Option, if exercised, will include the initial design specification and capabilities description necessary to build a prototype solution in Phase II.

PHASE II: Develop and demonstrate a prototype of the concept for an EW alert analysis, prioritization, and monitoring application meeting the requirements contained in the Description. Deliver the software prototype to the Government along with full software interface descriptions and any ancillary software needed to demonstrate the application.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Navy use. Since the Phase II effort result is a prototype that is not necessarily demonstrated on a tactical system, assist in integrating the alert analysis, monitoring, and display software into the EW display tactical code. Assist in certification of the resulting tactical code. Assist the Government in testing and validating the performance of the resulting application, as integrated into the EW console. The alert display software can also be customized for additional applications such as other military systems (including radar and weapons displays) and for commercial systems such as air traffic control systems.

REFERENCES:

1. Haberkorn, Thomas, et al. "Traffic displays for visual flight indicating track and priority cues." IEEE Transactions on Human-Machine Systems 44, September 2014, pp. 755-766.
<http://ieeexplore.ieee.org/document/6898824/>
2. Moacdieh, Nadine and Sarter, Nadine. "The effects of data density, display organization, and stress on search performance: an eye tracking study of clutter." IEEE Transactions on Human-

Machine Systems 47, December 2017, pp. 886-895.
<http://ieeexplore.ieee.org/document/7971994/>

KEYWORDS: Electronic Warfare; Human-Machine Interface; Alert Monitoring; Cognitive Science for EW; Embedded Training; Algorithms for EW displays

N211-051 TITLE: Non-acoustic, High Fidelity, Short Range Underwater Tracking System

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a non-acoustic underwater Mine Countermeasures (MCM) tracking system with accuracies suitable for signature measurements within 1-2 yards.

DESCRIPTION: This SBIR topic seeks technology to reduce the susceptibilities of Explosive Ordnance Disposal (EOD) MCM equipment in a broad range of contested operational environments, specifically high-risk mine areas while improving EOD ability to enable fleet access and maneuver in challenged sea space. The technology will build a more lethal force and improve fleet readiness. Current available systems use various forms of acoustic tracking beacons which interfere with the acoustic data collection, require very accurate placement of additional hydrophones and do not have the centimeter or inch level of accuracy needed for the small items (UUVs, ROV Divers) used by Expeditionary Mine Countermeasures (EXMCM).

Navy Expeditionary forces responding to underwater threat objects require an ability to safely deploy and operate Maritime Expeditionary Mine Countermeasures Unmanned Undersea Vehicle (MEMUUV) systems and Maritime Expeditionary System of Systems Response (MESR) Remotely Operated Vehicles (ROVs) in a broad range of environments. Navy Expeditionary forces thus require stringent signature measurement and control, which can only be achieved with highly accurate tracking. Once high accuracy tracking is implemented, electromagnetic and acoustic signature reduction techniques can be applied at exactly known sources on the EXMCM EOD equipment.

After measuring first generation USN UUV and ROV signatures using arrays of acoustic sensors at multiple field tests, it became clear that the existing acoustic tracking techniques did not have the tracking range-position spatial resolution required to provide the level of signature fidelity necessary to adequately characterize for minefield suitability purposed, EOD systems for the purposes in which they are employed.

Existing systems normally involve the attachment of a known high-frequency, high-power, and narrow bandwidth acoustic transponder on the vessel under test, such that through the detections on multiple sensors located on the range, a determination of range can be accomplished. For fairly large USN vessels that create more noise than smaller units, increased stand-off ranges are possible, and errors or variations in range accuracy are much more tolerable.

A tracking system would help improve the ability to ensure minefield suitability of EXMCM EOD equipment (e.g., UUVs, ROVs, diver-held sensors as well as other equipment operating in mine danger areas [e.g., EOD boats]) and supports USN UUV systems as defined in the Secretary of the Navy Report to Congress on Autonomous Undersea Vehicle Requirements for 2025.

UUV tracking experience for measurements of <10 yards sensor to source highlighted that acoustic tracking technology achieved marginal accuracy, if at all, and required dynamic positional accuracy for close-in high-fidelity tracking. The goal of this SBIR topic is to design a system to provide accurate, real-time tracking capability in both sea water and fresh water locations. The tracking accuracy threshold is plus or minus 7 inches with an objective of plus or minus 3 inches at a 6-foot Closest Point of Approach (CPA) over a dynamic range of plus or minus 60 feet from CPA. This capability would allow signature reduction prioritization in the developmental stages of EOD equipment production as well as lowering the risk of expensive equipment loss when employed in combat. Naval Surface Warfare Center Carderock Division (NSWCCD) will test the prototype tracking at an appropriate site to verify 3" accuracy at 6 feet both static (in a tank [e.g., TRANSDEC]) and dynamically in a tank [e.g., CD tow tank]).

The Phase I effort will not require access to classified information.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Design a concept for a tracking system that can provide accuracies on the order of inches while tracking an underwater object in real time as detailed in the Description. Demonstrate the feasibility by modeling and simulation as well as technical and engineering design review. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a prototype tracking system and validate it with accuracies suitable for signature measurements within 1-2 yds. NSWCCD will test the prototype in an appropriate tank and document the tracking algorithm and fidelity (improved range accuracy of 3 inches at 6 feet). Demonstrate the system with a full underwater acoustic measurement array. Plan and conduct a requirements analysis session with the Navy technical team to further refine source mounting, feasibility (e.g., determine if anything that's attached to the unit for tracking affects the performance of the unit, if any additional sensor needed for the system should be added to systems being measured) and UUV interface requirements for a prototype tracking system. Refine the demonstration prototype of an improved tracking system with a designated small or medium-sized Government Furnished Equipment and Information (GFE/GFI) UUV and/or ROV asset.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Work with the Navy personnel and contractor Field Service Representatives (FSRs) to transition the technology to Navy use and gain additional detail on the designated EOD systems that ultimately would be used for integrating the improved tracking system. Support the Navy testing and evaluation team with introduction of the tracking system as a potential ranging capability for UW EOD systems.

A potential platform for this tracking system is the Underwater Signature Measurement System (USMS), a prototype multi-influence point ranging sensor system developed jointly by the NSWCCD and industry partners, consisting of advanced magnetic, electric, pressure, and acoustic sensors that have been selected and integrated into two qualification units consisting of a cylinder (USMS#1) and a hemisphere (USMS#2). USMS#2 is the proposed unit to be upgraded and made suitable for EOD UUV/ROV vehicle tracking and underwater EM communication.

Additionally, several commercial companies produce UUVs and ROVs for U.S. and allied military applications including mine countermeasures, port protection, underwater unexploded ordnance remediation, and naval oceanographic mapping missions. These missions may benefit from the improvements in off hull tracking.

The tracking system could also be adapted to small and medium-sized UUVs used for underwater tracking and surveillance tasks by the gas and oil industry, fisheries, scientific research communities, commercial diving and salvage industries; and have a wide applicability in high accuracy tracking applications, even outside of signature applications.

REFERENCES:

1. Luo, Junhai, Han, Ying and Fan, Liying. "Underwater Acoustic Target Tracking: A Review." Sensors (Basel), 2 Jan 2018. <https://www.ncbi.nlm.nih.gov/pubmed/29301318>
2. Mabus, Ray. "Report to Congress – Autonomous Undersea Vehicle Requirements for 2025." <https://news.usni.org/wp-content/uploads/2016/03/18Feb16-Report-to-Congress-Autonomous-Undersea-Vehicle-Requirement-for-2025.pdf#viewer.action=download>

KEYWORDS: Unmanned Undersea Vehicle; UUV; Remotely Operated Vehicles; ROV; Mine Countermeasures; MCM; Expeditionary Mine Countermeasures; ExMCM; Original Equipment Manufacturer; OEM; Magnetic and Acoustic Influence Signature of UUVs

N211-052 TITLE: Navigational Positioning Source Using Very Low Frequency Signals

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop receivers and algorithms that employ Very Low Frequency (VLF) radio signals from existing United States Government (USG) ground stations to determine position and velocity information at sea on a United States Navy (USN) ship or submarine.

DESCRIPTION: The success of U.S. Navy missions depends on personnel and platforms having access to accurate and reliable position, velocity, attitude, and time information. Maritime platforms specifically need this information continuously to support safety of ship, weapons deployment and network communications, and geo-registration. The DoD developed a Global Positioning System (GPS) to provide accurate, worldwide, all-weather, continuous position and time information to warfighters. As a result, GPS is the primary positioning and time source for maritime surface platforms. However, GPS is susceptible to interference and may not be continuously available in a time of conflict. Consequently, backups to GPS are needed for positioning and timing information to meet mission support.

Many military platforms also deploy inertial navigation systems along with GPS. Inertial navigation systems (INSs) are continuous, all-weather sources of position, velocity, and attitude information. INSs are not susceptible to interference in the same manner as GPS. Also, many maritime platform missions can be met with a military grade INS. INSs drift over time and require periodic fixes to reset their position. Typically, an INS will be corrected by fixes to GPS or some other fix source, such as a visual source, a radar contact or some other navigational feature. In the event of a prolonged period of GPS not being available and no other usual sources being available, additional sources of position fixing are needed.

Using VLF signals to aid navigation has its origins from the middle of the 20th century with the OMEGA hyperbolic navigation system being the most widely used system by the U.S. (Russia had a comparable system known as ALPHA.) OMEGA had 8 ground-based transmitters strategically located around the world and provided 24-hour global coverage, operating in the 10-14 kHz range. In these hyperbolic navigation systems, transmitters were synchronized by using one of the transmitters as the trigger for the other to broadcast after a fixed known delay. A receiver measured the signals from the transmitters and a comparison was made between the known delay and the measured delay, and the location of the receiver was determined to lie on a curve that was a function of this delay. Using two or more pairs of transmitters allowed for an accurate horizontal position measurement.

The OMEGA navigation system had accuracy in the 1-4 nautical mile (nmi) range, which was dependent on a number of factors. Synchronizing of the two transmitters over transmitter distances of thousands of miles was challenging in the mid-20th century. This error source would later be overcome using atomic clocks at all transmitter sites; however, aligning clocks at multiple sites was still problematic.

Additionally, the paths of VLF signals from transmitters to receivers are severely distorted by the ionospheric changes along the very long transmission paths. The OMEGA navigation system ceased transmissions in 1997 with the advent of alternative systems that had greater accuracy, such as GPS.

However, near the end of OMEGA operations, many of the technical challenges limiting VLF navigation's accuracy performance were solved, including improved ionospheric modeling and better signal processing.

Recently there has been renewed interest in positioning using VLF signals. A terrestrial-based position and timing source is desired as a backup to GPS, and an OMEGA-like VLF system can provide global coverage with just a few transmitters. VLF signals are very difficult to interfere with because of the high power with which they are transmitted. DARPA's Spatial, Temporal, and Orientation Information in Contested Environments (STOIC) program sought to achieve GPS-level or better performance in part using VLF signals. The STOIC program demonstrated much improved positioning over OMEGA by creating a stable VLF signal, developing high fidelity physics models of the ionosphere along the signal path and improved signal processing at the receiver.

The Navy seeks innovative technology that can mature the VLF navigation technology to support navigation resilience on U.S. Navy shipboard platforms. The focus of this SBIR topic is expected to center on improved receivers for processing the VLF signals, and algorithms to extract the signals that can be used to develop accurate position and velocity to estimate INS errors without a backchannel communications need for ionospheric corrections. Position fix accuracy should be within 0.5 nmi (dRMS) or better, with fixes available at least 12 hours per day. Short-term velocity output performance should be within 0.1 knots or less (rms, each horizontal axis) over 1 hour. An additional research focus will be on modeling the error characteristics of the VLF-derived position and velocity reference, as this model will need to be incorporated into real-time Kalman filter algorithms of an inertial navigation system. VLF antenna will be a contractor selection, but must not exceed 22" x 22" x 22" in volume. Electronics must fit within a standard 19" electronics rack and not to exceed four electronic rack units (RU). However, receiver and algorithms should be adaptable to both purpose-built and existing VLF shipboard antenna systems.

The technology sought will develop the algorithms and receiver technology that will deliver reliable, consistent, and predictable position and velocity information providing known error characteristics.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for improved VLF system navigation algorithms and receivers. Demonstrate feasibility for obtaining accurate position and velocity from maritime platforms using existing Navy or purpose-built antennas. Demonstration will show that the concept meets the requirements as described in the Description and includes analysis, modeling, and simulation. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype of an improved VLF system navigation algorithm(s) and receiver(s). The prototype will show that it achieves the parameters described in the Description. Deliver the prototype to be independently evaluated by the Government to determine if the technology has the potential to meet the Navy's performance goals for position and velocity accuracy using VLF signals.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. Develop a mature prototype capable of testing on a maritime platform. Mature any key algorithms, software or hardware. Field test the system on a maritime platform to demonstrate performance of the mature system. Compare the system's demonstrated performance with GPS to determine the usefulness and the applicability of this technology in GPS-challenged environments.

Potential commercial applications include navigation and positioning in mining, aviation, surveying, agriculture, marine, and recreation. Department of Navy could use the technology for multiple missions including surface, submarine, and air navigation.

REFERENCES:

1. DARPA PNT Program Overview of 1 Aug 2017 b. Broad Agency Announcement Spatial, Temporal and Orientation Information in Contested Environments (STOIC) Strategic Technology Office DARPA-BAA-14-41 June 3, 2014. <https://www.gps.gov/governance/advisory/meetings/2019-06/burke.pdf>
2. Sasmal, S., Palit, S. and Chakrabarti, S.K. "Modeling of long-path propagation characteristics of VLF radio waves as observed from Indian Antarctic station Maitri." J.Geophys. Res. Space Physics, 120, 2015, pp. 8872–8883, <https://doi:10.1002/2015JA021400>
3. Newman, Edward M. "The Biggest Little Antenna in the World." PowerPoint Presentation, AP-S, November 14, 2012. <http://arlassociates.net/Newman%20AP%20Presentation.pdf>
4. "Omega." Skybary. <https://www.skybrary.aero/index.php/Omega>
5. Barr, R., Jones, D. Llanwyn and Rodger, C.J. "ELF and VLF Waves." 14 June 2000, Journal of Atmospheric and Solar-Terrestrial Physics 62, 2000, pp. 1689-1718. <https://www.sciencedirect.com/science/article/abs/pii/S1364682600001218>

KEYWORDS: Very Low Frequency; Navigation; OMEGA; STOIC; Atmospheric Signal Propagation; RF Receivers and Antenna

N211-053

TITLE: Nickel-Zinc Submarine Main Storage Battery

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop a Nickel-Zinc (NiZn) battery system that does not rely on Lithium Ion (Li-ion) technology and would replace lead-acid battery system with a more efficient, environmentally safe, maintenance free, and long life battery in the form of a large-format (1,000Ah+) NiZn battery with cycle life and capacity maximized within the design.

DESCRIPTION: The U.S. Navy Submarine Fleet main storage battery currently employs Valve-Regulated Lead-Acid (VRLA) technology to meet platform energy and power requirements. However, with the increasing reliance of electronics on large platforms, future mission needs will require additional battery capacity beyond what current lead-acid battery technology is able to provide. The submarine battery compartment cannot be expanded, so VRLA technologies have seemingly reached operational limits. Therefore, there is a mounting need to transition from the current VRLA battery to an alternative battery technology with a higher energy density and improved reliability. Accordingly, NiZn battery technology has the potential to bridge the energy density gap until Li-ion battery technology can be made reliably safe for submarine applications. Further, submarines continue to see electrical load growth requiring more main storage battery capacity in the same volume. The development of a large-format NiZn battery will offer the needed battery capacity increase on submarines while offering a safer alternative to Li-ion batteries, which, though energy dense, come with a high risk of failure. A Li-ion failure onboard a submarine has the potential to be a catastrophic event. The Navy could potentially delay, or eliminate altogether, a Li-ion transition requirement allowing for lower risk design cycle.

NiZn is an emerging battery technology optimized for high capacity and long life while also delivering high power in an environmental friendly and safe chemistry. NiZn batteries have a projected increase of about 50% the capacity of lead-acid batteries, with a 25% weight reduction given the same footprint. Currently, prototype and commercial NiZn batteries are of small-format design. Large-format, scaled-up versions of the NiZn designs are not commercially available. Submarine main storage battery replacement will require scale-up of small-format NiZn technology to submarine-specific sized large-format 1,000Ah+ NiZn batteries with cycle life and capacity maximized within the design. The NiZn battery concept must achieve 75% of capacity through 200+ Navy Equivalent Charge/Discharge cycles. Feasibility of concept will be determined through various characterization and operational testing at NSWC Crane. The developed and delivered prototype large-format batteries will be provided to NSWC Crane at the end of Phase II for testing and evaluation. NSWC Crane has the expertise to test and aid development of large-format NiZn batteries using lessons learned from VRLA efforts. The focus of testing at Crane will be to validate the performance of the large-format batteries through characterization and Operational Cycle Life (OCL) testing. OCL will be performed to evaluate the ongoing performance and expected cycle life of the design by pushing the prototypes through various charge and discharge rates over a period of 200+ Navy Equivalent Cycles (NECs). The prototypes will be tested to obtain performance data and demonstrate viability of NiZn as a replacement for Submarine VRLA main storage battery.

PHASE I: Develop a minimum 1,000 amp-hour NiZn battery concept that can achieve 75% of capacity through 200+ Navy Equivalent Charge/Discharge cycles. Develop a design and fabrication approach to scale small-format NiZn to large-format and determine technical feasibility. The initial design concept should include expected cycle life, performance, and manufacturability of large-format NiZn cells and batteries. Feasibility of concept will be determined through various characterization and operational testing at NSWC Crane. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype in Phase II.

PHASE II: Develop and deliver a prototype large-format NiZn cells and batteries based on Phase I work and Phase II Statement of Work (SOW) for demonstration, testing and validation which will include characterization testing to understand the range of capacities through various discharge rates as well as operational testing to validate long-term performance. Prototype will be provided to NSWC Crane at the end of Phase II for testing and evaluation.

PHASE III DUAL USE APPLICATIONS: Utilize the Phase II prototype testing and analysis results to assist the Navy in transitioning to Navy use. Update design and system development. Integrate Battery Management System (BMS) requirements (furnished by the Navy based on results of testing and evaluation) into final NiZn large-format cells and batteries.. Implement full-scale design manufacturing and transition the end product to the Navy for submarine main storage battery validation, testing, qualification, and certification at NSWC Crane with PMS 392 support.

This technology has potential commercial transition to other applications such as aircraft, alternative energy, and data center energy storage. Large-scale NiZn batteries can easily be integrated in current lead-acid applications such as engine start, trucking, and large-scale data centers.

REFERENCES:

1. Parker, Joseph F., Chervin, Christopher N., Pala, Irina R., Machler, Meinrad, Burz, Michael F., Long, Jeffrey W. and Rolison, Debra R. "Rechargeable Nickel-3D Zinc Batteries: An Energy-Dense, Safer Alternative to Lithium-ion." Science, April 2017: Vol. 356, Issue 6336, pp. 415-418. <https://science.sciencemag.org/content/356/6336/415>.
2. Chamoun, M., Hertzberg, B., Gupta, T. et al. "Hyper-Dendritic Nanoporous Zinc Foam Anodes." NPG Asia Mater 7, e178 (2015). <https://doi.org/10.1038/am.2015.32>

KEYWORDS: Submarine Main Storage Battery; Nickel-Zinc Battery; Nickel-Zinc Replace Lead-Acid; Nickel-Zinc Alternative Energy; Rechargeable Nickel-Zinc Batteries; Safer Alternative to Lithium-ion.

N211-054 TITLE: High Strength Composite System for Ships

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a high strength composite material that meets U.S. Navy standards for Flame, Smoke and Toxicity Requirements.

DESCRIPTION: Ship building programs throughout the U.S. Navy have begun to increase the use of composite structures throughout the ship, i.e., Landing Craft, Air Cushion (LCAC) and Ship-to-Shore Connector (SSC) ramps, LPD 17 mast, and DDG 1000 deckhouse. These composite structures offer lighter weight and better corrosion resistance than a similar metallic part. The composite systems include resin, filler fabric and the methodologies involved in building finished products in various forms with differing functions.

To date, identification of composite material solutions have required either relaxation of Flame/Smoke/Toxicity (FST) requirements (outlined in NAVSEA MIL-STD-3020, ASTM E84 and ASTM E662), compromise in material strength (durability) or increase in weight. Fatigue life calculations are based on 270 x 10⁶ cycles, using allowable material properties. The Navy is seeking a new composite material system that provides a more agile forward force maneuverability and posture resilience and all the benefits of using composites while still meeting structural requirements for strength and durability and maintaining Naval fire resistance performance requirements.

PHASE I: Develop a concept for a composite system, which will meet FST requirements while allowing for the needed strength and durability characteristics. Demonstrate the feasibility of the concept in meeting Navy needs and establish that the concept can be developed into a useful product for the Navy. Feasibility will be established by coupon development, laboratory testing and demonstration of the materials. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop and test the new system prototype composite system. Test in accordance with NAVSEA MIL-STD-3020MIL-STD-3020, ASTM E84 and ASTM E662 as well as plastic, elastic and failure pull testing to demonstrate strength characteristics. Product performance will be demonstrated through prototype evaluation, modeling, analytical methods, and demonstration over the required range of parameters including numerous cycles. A Phase III development plan and cost analysis will be prepared to outline transition of the technology to Navy use. Provide detailed drawings, code and specifications in Navy-defined format. In addition, provide support to shepherd the new composite system through the Navy technical approval process.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the new composite system for Navy use on shipbuilding programs beginning with LCAC and SSC Air Cushioned Vehicles. Once a new composite system is validated it is expected to have impact across the full range of composite usage in the Navy. Commercial applications include all aspects of composites including aerospace, hovercrafts, airplanes, helicopters, ferries, the oil and mineral industry, automotive, cold climate research, and exploration.

REFERENCES:

1. Lv, Qiang, Huang, Jian-Qian, Chen, Ming-Jun, Zhao, Jing, Tan, Yi, Chen, Li and Wang, Yu-Zhong. "Effective Flame Retardant and Smoke Suppression Oligomer for Epoxy Resin."

Industrial & Engineering Chemistry Research 2013.

<https://pubs.acs.org/doi/abs/10.1021/ie400911r>

2. Chen, Xilei, Liu, Lei and Jiao, Chuanmei. "Influence of Iron Oxide Brown on Smoke-Suppression Properties and Combustion Behavior of Intumescent Flame-Retardant Epoxy Composites." *Advances in Polymer Technology*, Winter 2015, Volume 34, Issue 4. <https://onlinelibrary.wiley.com/doi/full/10.1002/adv.21516>
3. MIL-STD-3020, DEPARTMENT OF DEFENSE STANDARD PRACTICE FIRE RESISTANCE OF U.S. NAVAL SURFACE SHIPS, 7 November 2007. http://everyspec.com/MIL-STD/MIL-STD-3000-9999/MIL-STD-3020_11625/
4. ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials, 2007. <https://www.astm.org/search/fullsite-search.html?query=ASTM%20E84&>
5. ASTM E662, Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials, 2007. <https://www.astm.org/search/fullsite-search.html?query=e662&>

KEYWORDS: Ship-to-Shore Connector; Air Cushion Vehicle; Composites; Flame Smoke and Toxicity; Hovercraft; Composite Material System

N211-055 TITLE: High Dynamic Range and Low Noise Figure (NA) Integrated Microwave Photonic Transceiver for 6G mmWave Radio

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a compact high dynamic range and low noise figure integrated optical amplifier microwave photonic transceiver module for DoD 6G mmWave radio.

DESCRIPTION: The Navy seeks technologies that are oriented toward a deeper understanding of the upcoming 5G and future 6G communication systems which impose stringent requirements and challenges for hardware systems. The commercial state of the art consists of the 5G systems that are under development and will be deployed soon. These 5G systems utilize the lower millimeter-wave frequency low band (e.g., <6 GHz), while the high band (6-24 GHz) region has not yet been considered due to the lower transmission ranges and higher equipment density in a given area for the same coverage. 6G will operate above 24GHz and will have the similar challenges as 5G but on a higher scale. At present significant efforts have been devoted to developing low to mid band millimeter-wave circuit systems. The challenge is to develop a low-cost photonic integration of high speed active optical modulator, high speed photodetectors, and mmWave electronics. The benefit of this approach is to improve performance of the Navy's optical wireless communication throughput, security, and reliability.

To meet the Navy challenges, this topic shall be able to address Spectrum Supremacy as stealth communication for battle space supremacy; the Navy Focus Area for Expand the Advantage through increased capability; and a number of objectives within increased capability to have Navy battlespace supremacy and water-space management.

To overcome the transmission range of the standard microwave 5G network, the Navy is interested in an innovative hybrid approach of integrated optical and mm wave transmission. The new System architecture will support future 6G hybrid network systems, that will have significant bandwidth and data-rate improvements (x100-time improvement) over current 5G technology. This demand necessitates significant developments and investigations of different techniques that will enable the required data-rate and bandwidth capacities. Correspondingly, an innovative integrated microwave photonic 6G mm Wave radio transceiver features great advantages to address these issues when compared to traditional microwave/millimeter-wave approaches. Optical fiber enables large operating frequency and bandwidth for 6G networks (operating frequency from 100 GHz to 1000 GHz). However, the field of 6G is still a nascent area. To have 6G hybrid high data rate optical network, the integrated microwave photonic transceiver must overcome the crucial technical challenges in the receiver (RX) modulator's efficiency by achieving an ultra-low $V_{pi} < 1$ volt (where V_{pi} is the voltage drop needed to cause a 180 degree phase change) and the Transmitter (TX) photodetector's poor optical-to-mmWave power conversion efficiency. The company and the research institution should use the Open model base engineering environment, open source software such as C++, for the product development and documentation. The goal of this program

is to develop hybrid microwave photonic transceiver modules that can operate from 60GHz (5G) up to 200GHz (for future 6G). The transceiver should demonstrate greater than 10 percent fractional bandwidth. For 5G operation, the transceiver should enable a base station to demonstrate >10Gbps up/down link throughputs. For future 6G operation, the transceiver should enable >1Tbps throughputs.

PHASE I: Develop a concept for mmWave wide dynamic range and low noise figure integrated amplified Photonic system based on model-based engineering (MBE) as outlined in the Description. Demonstrate the feasibility of developing a compact size, weight, area, power, and efficiency (SWaPe) mmWave 6G radio transceiver that enables ultra-high efficiency conversion between mmWave and optical signals using integration microwave photonic implementation as discussed in the Description through simulation and identify the primary technical risks of the concept. The Phase I Option, if exercised, will include the initial design specifications and capabilities description for the ground fault detection and localization system; and develop a test plan and test procedures for the prototype to be developed in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop, demonstrate, and deliver a prototype low SWaPe mmWave 6G radio transceiver using integrated microwave photonics. The working prototype must address technical risks, validate the draft specifications, and demonstrate the functionality of the overall design. Develop, demonstrate, and deliver a prototype low SWaPe mmWave 6G radio transceiver using integrated microwave photonics at 60GHz or higher. The transceiver should demonstrate greater than 10 percent fractional bandwidth. The working prototype must address technical risks in developing integrated high speed linear optical modulators and high speed photodetectors, and their integration with millimeter electronics and swap antenna. The working prototype must demonstrate 6G base-station operation with >10Gbps up/down link throughputs. The Phase II work should also demonstrate a clear path for achieving future 6G operation at 200GHz band.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning of the technology to Navy 6G platform mmWave communication link into subsurface and surface platform. Document the design and capabilities of the modulator prototype developed under Phase II. Work with the Government to develop specifications. Provide support by finalizing and validating the compact low Vpi wide dynamic range, low noise figure, optical modulator based on needs of the Navy Electronic Warfare analog fiber optic links. Integrate and test the modulator with high dynamic range fiber optic links. Private Sector Commercial Potential: The development of compact, low Vpi wide dynamic range modulator has commercial potential for telecom applications such as cable TV, radio over fiber, etc.

REFERENCES:

1. Strinati, E. C.; Barbarossa, S.; Gonzalez-Jimenez, J.L.; Ktenas, D.; Cassiau, N.; Maret, L. and Dehos, C. "6G: The next frontier: From holographic messaging to artificial intelligence using subterahertz and visible light communication." IEEE Vehicular Technology Magazine, vol. 13, no. 3, 2019, pp. 42-50. <https://ieeexplore.ieee.org/document/8792135>
2. Kumar, Puneet; Sharma, J.K. and Singh, Er. Manwinder. "5G Technology of Mobile Communication." International Journal of Electronics and Computer Science Engineering 1265. <https://pdfs.semanticscholar.org/328e/121d173a57a6976013feb562f99557760eab.pdf>
3. Tripathi, Purnendu, S. M. and Prasad, Ramjee. "Spectrum Trading in India and 5G." Journal of ICT Standardization, Vol. 1, Issue 2, November 2013, pp. 159-174. https://www.riverpublishers.com/journal_read_html_article.php?j=jicts/1/2/3
4. Prasad, Ramjee, "Global ICT Standardisation Forum for India (GISFI) and 5G Standardization." Journal of ICT Standardization, Vol. 1, 2013, pp. 123-136. https://www.riverpublishers.com/journal_read_html_article.php?j=jicts/1/2/1
5. Farooq, Muhammad; Ishtiaq, Muhammad Ahmed; M Al., Usman. "Future Generations of Mobile Communication Networks." Academy of Contemporary Research Journal, Volume 2,

Issue 1, 2013, pp. 24-30.

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.404.333&rep=rep1&type=pdf>

KEYWORDS: Compact size, weight, area, power and efficiency; SWaPe; microwave photonic; mmWave; Dynamic range; Vpi; 6G communications systems

N211-056

TITLE: Propulsor Geometric Certification System

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and integrate a digital solution for naval propulsor repair and new manufacture geometric certification for greater war readiness, performance, and affordability.

DESCRIPTION: The certification of the geometric properties of propulsors are a key factor in meeting many Key Performance Parameters and Key System Attributes for United States Navy (USN) ships. Proper execution of propulsor geometric inspection and certification supports ship powering, signature, and vibration performance requirements. Current practice for USN propulsor certification requires the application of highly maintained sets of physical gages in a controlled and detailed process. The cost and time involved in this process can lead to delays in delivery to ship and degraded ship propulsor performance. The Navy seeks a fast and practical way to inspect and certify new and repaired propulsor assets to create a more resilient and agile logistics path and support on time delivery of ships and submarines.

USN propulsors are large, finely machined assets that have unique and complex manufacturing tolerances, both of which present challenges to geometry certification and challenge the current state of the art in digital surface scanning and assessment. Certification of propulsors requires both very tight local surface profile tolerance over a wide area, as well as local and global derived geometric characteristic tolerances unique to propulsors. Current commercially available components lack the required speed and accuracy of data collection, the analytical capability to assess against relevant propulsor tolerances, and the capability to easily direct repair; and they are not integrated systems. Development is required to allow for a 23' diameter x 5' deep volume to be captured on a newly machined metallic surface at sufficient accuracy to verify tolerances of 0.005". Specialized software development is required to process the captured data in a manner consistent with USN propulsor tolerances. Innovation can also be applied to the interpretation of the data analysis and its application in identifying corrective actions and conveying them to the machinist.

This SBIR topic seeks to develop an integrated survey, analysis, and reporting system for use in new manufacture and repair of USN propellers. The survey system shall be able to measure a representative NiAlBr propeller of 23' diameter to a precision of at least 0.00025" in less than 6 hours. The analysis software shall quality control the surveyed data, and analyze it in a fashion consistent with USN guidance on propeller dimensional inspection in near-real time with minimal user involvement.

The system will be assessed against a standard inspection of a test monobloc propeller or controllable pitch propeller (CPP) blade and a process review of the analysis method. The system shall document the blade condition and aid the inspector/machinist in identifying dimensional exceedances and coordinating corrective actions.

PHASE I: Propose a concept for an integrated system solution for geometric inspection, evaluation, and result output of monobloc propellers and controllable pitch propeller (CPP) blades. Demonstrate the capability to optically evaluate a representative article to the required accuracy. Provide a concept for blade dimensional analysis and demonstrate ability to produce and develop similar software. Provide and demonstrate a concept for utilizing the analysis data to assist in the remediation of the blade to determine feasibility. The Phase I Option, if exercised, will include initial design specifications and description of capabilities to build a prototype in Phase II.

PHASE II: Build and demonstrate a prototype system of the solution on a USN asset provided by the Government team, i.e., a USN propeller and a controllable pitch propeller (CPP) blade will be arranged in a repair facility along with required reference information. Demonstrate that the prototype can perform all aspects of the inspection process on the provided propeller and CPP blade, including setup, data acquisition, data analysis, and reporting. Assess prototype performance against a standard inspection of the test articles, as well as on the design specifications and capabilities outlined in the Description.

PHASE III DUAL USE APPLICATIONS: Assist the Navy in transitioning the technology by providing systems (4-20) for procurement by 2SCog Propulsion Program, USN Regional Maintenance Centers or other NAVSEA facilities, and/or industry vendor partners as well as training in their use. The resulting systems should include surveying devices and associated items required for operation, analysis software, and any software or items required for output/utilization of analysis data.

These systems will be used to support all Navy surface ship assets, particularly DDG, LPD, CVN, and LCS classes. These systems will allow rapid evaluation of units in the field and in facilities, providing better and faster assessment of required repairs and performance impacts. This would allow for a reduction in repair lead times of roughly 60-360 days, creating a shorter, more flexible logistics chain to support fleet needs. This would also reduce non-recurring engineering (NRE) and capital costs on designing and manufacturing the blade gages required for traditional inspection, 0.5-2M over the next five years, as well as virtually eliminating the \$50-200K expense of each inspection leading to more affordability in ship procurement and availabilities. Not including new delivered ships or emergent repairs, the 2SCog program plans to procure at least 46 new or refurbished propellers and blade sets over the next 5 years. This system could also likely be extended to virtually any foil-like high performance part, such as turbines or aviation for both DoD and commercial applications.

REFERENCES:

1. Allen, David W., et al. "Propeller Geometric Parameter Extraction From Inspection Data Clouds." *Journal of Ship Production*, Vol. 21, No. 4, NOV 2005, pp. 203-208.
<https://www.onepetro.org/journal-paper/SNAME-JSP-2005-21-4-203>
2. Allen, David W., Harsh, Albert F., and Machin, James D. "Computer-Aided Marine Propeller Inspection Data Analysis." *Naval Engineers Journal*, Vol 107, No. 2, MAR 1995, pp. 33-40.
<https://www.ingentaconnect.com/contentone/asne/nej/1995/00000107/00000002/art00010>
3. Li, Feng; Stoddart, David and Zwierzak, Iwona. "A Performance Test for a Fringe Projection Scanner in Various Ambient Light Conditions." *Procedia CIRP - 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering*, Vol 62, DEC 2017, pp. 400-404.
<https://www.researchgate.net/publication/317047660>
4. Contrarotating Prop Set 5525/5526 – *CAD Program Required* - This link provided will download a compressed file which will contain a representative propeller surface geometry file in ASCII Initial Graphics Exchange Specification (IGES) format and text description file which provides a typical example of some of the Navy standard features which would need to be inspected by the proposed system. This is provided as an example article for information, it is not the Phase II article, nor does it represent all of the challenges associated with the SBIR (overlapping blades,

for example). While this is an example of standard surface definition formatting, proposers are free to outline modifications to this format as required by their system. https://urlprotection-sjl.global.sonicwall.com/click?PV=1&MSGID=202101112029300094983&URLID=11&ESV=10.0.6.3447&IV=32811331931958146CC374749BBBCFA8&TT=1610396972206&ESN=iUeqoQ4QKRrxm%2BBRI%2FME4Zs%2BU1TzkE5C3BGLpgLkOQA%3D&KV=1536961729279&ENCODED_URL=https%3A%2F%2Fnavysbir.com%2Fn21_1%2Fp5525.zip&HK=C5224C27B3A72E7E2E3DF1BACC1357E3D964692EF98619F686F6D6525550812D

KEYWORDS: Propeller Inspection; Airfoil Metrology; Propeller Gages; Geometry Certification; Laser Scanning; Optical 3D Scanning

N211-057 TITLE: Flight Deck Tie Downs

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop an advanced non-corroding material to use in replacement DDG-51 FLT III Helicopter Flight Deck Tie Downs.

DESCRIPTION: The U.S. Navy's DDG-51 Class Destroyer helicopter flight deck utilizes tie downs to anchor and secure the helicopters on the flight deck. While the tie downs should ideally last for the 40-year service life of the vessel, in practice they fail due to corrosion and often need replacement. The corrosion of a flight deck tie down is a grave hazard, as its failure at an inopportune time could cause extensive damage to valuable equipment and endanger the lives of the sailors aboard. Anti-corrosion coatings and coverings have not been effective at eliminating the problem. The Navy requires the development of an innovative, noncorroding material to replace the existing flight deck tie down.

The development of a noncorroding material to meet the Navy need will require significant innovation to overcome several technical challenges, it must withstand saltwater immersion, exposure to industrial chemicals and jet fuel, and exposure to ultraviolet radiation; and be fire resistant and resistant to galvanic corrosion. Attaching tie downs of a new material class to the deck may require innovative welding techniques or advanced mechanical fastening methodologies. Whatever method is developed, it must be able to meet the same requirements as the current Navy tie down. Required maintenance must be able to be performed by Navy personnel. The joining method must also be watertight to the deck and prevent corrosion below the tie down.

Research into noncorroding materials has identified materials that could potentially be developed to meet the Navy's need. Some of the more promising possibilities include Advanced Thermoplastic Composites, High Strength Metallic Glass, and Novel Metallic Alloys. However, no material within these categories has been adequately demonstrated to be a replacement for the strength and durability provided by steel. Thermoplastic Composites and Metallic Glass would most likely require mechanical joining. Novel Metallic Alloys might be easier to weld to the deck, but care must be taken to prevent galvanic corrosion in the steel. All these materials would need to pass extensive testing to demonstrate that they can replace the existing flight deck tie downs and withstand the repeated heavy loads required to anchor the ships assigned aircraft as defined in NAVSEA Drawing 803-1916300 Rev P (2013), "Hull Standard Drawing Aircraft Securing and Engine Run-Up Fittings", July 2013. Innovation will be required to reduce acquisition costs and produce a viable product for the Navy.

PHASE I: Develop a concept for an innovative noncorroding material for Flight Deck Tie Downs that meets the requirements described above. Demonstrate the feasibility of the concept in meeting Navy needs and establish that the concept can be developed into a useful product for the Navy. Feasibility will be established by test of a material sample that will be analyzed in such a way that its failure mechanism will be representative of the larger product supported by finite element analysis. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build and demonstrate a prototype in Phase II.

PHASE II: Based on the results of Phase I and the Phase II Statement of Work (SOW), develop and deliver at least one prototype tie down for evaluation to determine capability in meeting the performance goals defined in the Phase II SOW. Product performance will be demonstrated through prototype evaluation, modeling, analytical methods, and demonstration over the required range of parameters including numerous cycles. Perform an extended test in a maritime environment to refine the prototype(s)

into a design that will meet Navy requirements. Prepare a manufacturing and development plan to transition the noncorroding tie down to Navy use. Support the Navy in transition planning and initiation of the Flight Deck Tie Down to Navy use. Develop installation and maintenance manuals for the tie down to support transition to the fleet.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the tie down technology to DDG-51. Potential private sector uses for advanced noncorroding materials include both the automotive and aerospace industries. Other commercial applications include architecture and maritime use.

REFERENCES:

1. Mavhungu, S.T.; Akinlabi, E.T.; Onitiri, M.A. and Varachia, F.M. "Aluminum Matrix Composites for Industrial Use: Advances and Trends." *Procedia Manufacturing*, Volume 7, 2017, pp. 178-182. <https://www.sciencedirect.com/science/article/pii/S2351978916302086>
2. Wu, Fu-Fa; Chan, K.C.[Jiang, Song-Shan; Chen, Shun-Hua and Wang, Gang. "Bulk Metallic Glass Composite With Good Tensile Ductility, High Strength and Large Elastic Strain Limit." *Scientific Reports* 4, Article number: 5302, 2014. <https://www.nature.com/articles/srep05302>
3. N211-057-Reference_Document_803-1916300-REV-P https://navysbir.com/n21_1/Topic-N211-057-Reference_Document_803-1916300-REV-P.pdf

KEYWORDS: Noncorrosive Material; Corrosion Resistance; Flight Deck Tie Downs; Metallic Glass; Advanced Thermoplastic Composite; Novel Noncorroding Metallic Alloy.

N211-058 TITLE: Automated Unmanned Systems (UxS) Boundary Protection Capability

RT&L FOCUS AREA(S): Cybersecurity

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop solutions that maximize use of automated network configuration management, machine learning (ML), advanced data analytics, Security Incident and Event Monitoring (SIEM), and decision analysis to execute unmanned systems UxS missions in a cyber-contested environment.

DESCRIPTION: The Navy seeks development of software, or a combination of software and hardware, to provide advanced cybersecurity capabilities in accordance with Navy Cybersecurity Technical Authority Standards Naval Systems Command Enclave Process v1.0 (dated 19 Sep 2017) and Defense-in-Depth Functional Implementation Architecture (DFIA) Standard (STD-DFIA-004R0), and the National Institute Standards for Technology Special Publication 800-53 rev 4 to UxS vehicles (e.g., Medium Displacement Unmanned Surface Vehicle [MDUSV], Medium Unmanned Surface Vehicle [MUSV], Large Unmanned Surface Vehicle [LUSV]), as well as support the needs of ships and vessels with reduced crew complements (e.g., FFG(X), Littoral Combat Ship [LCS], Military Sealift Command [MSC] ships). The solution provides an effective platform boundary that enables UxS vehicles to operate in a cyber-contested environment. The contested environment includes denial of services (DOS), man-in-the-middle [MITM], and unauthorized data exfiltration from both internal and external actors. The hardware and software may include technologies such as intrusion protection systems (IPs), intrusion detection systems (IDSs), and SIEM.

To ensure interoperability with PMS 406 portfolio, the solution must comply with the Unmanned Maritime Autonomy Architecture (UMAA), which establishes a standard for common interfaces and software reuse among the mission autonomy and the various vehicle controllers, payloads, and Command and Control (C2) services in the PMS 406 portfolio of UxS vehicles. The UMAA common standard for Interface Control Documents (ICDs) mitigates the risk of vendor lock from proprietary autonomy solutions; effects cross-domain interoperability of UxS vehicles; and allows for open architecture (OA) modularity of autonomy solutions, control systems, C2, and payloads. The Navy will provide the open standards for UMAA upon award of Phase I.

The Navy is seeking a broad range of emerging technologies that take advantage of commercial advances in network monitoring and management, SIEM data analytics, and ML to detect cybersecurity anomalies and automatically reconfigure network control points to isolate cyber events and preserve mission critical functions. No current commercial technologies exist that have the military applications that the Navy seeks, without significant tailoring to meet mission specific requirements.

Commercial solutions for network management, SIEM analysis, and system configuration often presume highly skilled humans in the loop or on the loop to evaluate the overall health of a network and execute (or at minimum, approve) changes to network configurations prior to execution. The Navy is interested in solutions that execute these functions without human intervention or supervision to perform tactical UxS missions.

In execution, these solutions would monitor traffic flow across multiple network enclaves within a UxS vehicle, make automated decisions regarding how to reconfigure the network to isolate anomalous behavior, and provide supervisory control of network traffic to enable/prioritize flow of mission-critical data flow while protecting the vehicle from horizontal escalation of anomalous traffic patterns.

The small business solution could take advantage of ML to integrate with commercially available SIEM and network configuration technologies. The solution should demonstrate the ability to identify anomalies and automate the process for identifying the appropriate responses needed to isolate the anomalies and implementing the appropriate network changes. Solutions must be effective without human intervention, given a number of pre-approved parameters.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Provide a concept to solve the Navy's problem and demonstrate the feasibility of that concept. Assess the feasibility by including at least one cyber table top (CTT). Identify the product(s) that comprise the overall solution, which may be either software or a combination of hardware and software based on Commercial off the Shelf (COTS) technology solutions and in accordance with the UMAA standards for physical and logical interfaces for ports, protocols, and services. Demonstrate feasibility using techniques such as modeling and simulation or demonstration testing in a commercial laboratory. As an example, propose a demonstration of a ML algorithm that analyzes SIEM data and issues a control to a network management device that changes the configuration of a network host. The Phase I demonstration could include human-in-the-loop supervisory control, provided the company explains how follow-on phases would fully automate the control function. Companies are expected to propose a specific plan for testing concept feasibility as part of their proposals.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver two prototype systems for testing and evaluation based on the statement of work (SOW) and Phase I results. The solution must demonstrate full automation (i.e., no human intervention required) of the process to detect an anomaly, determine the appropriate response, and execute the network configuration changes necessary to isolate the anomaly while still enabling mission-critical traffic flow.

The prototype system will vary based on the company's proposed approach, but it may include hardware and software. The hardware may be a commercial system, a Navy-provided system, or a combination of commercial and Navy-provided systems. The prototype will be evaluated in a Navy lab or at-sea environment. If the prototype is evaluated at sea, it may be evaluated on a manned or unmanned platform as appropriate for the solution. The Navy may opt to choose a surrogate platform for at sea testing based on availability of assets. Additional laboratory testing, modeling, or analytical methods may also be appropriate depending on the company's proposed approach. The test location will be at the USS Secure.

The system will be evaluated on its ability to with stand cyber-attacks (e.g. DOS, MITM) and the exfiltration of information from both internal and external threat actors. The testing and evaluation process will be accomplished through penetration testing. The personnel overseeing the tests will include representation from PMS 406. In general, two prototype articles should be provided to the government for testing, at least three months prior to the end of Phase II. A Phase III development plan will be required at the end of Phase II.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology (i.e., software integrated with Navy-provided hardware, or software integrated with company-provided hardware) to Navy use through system integration, testing support, software and hardware documentation, and limited hardware production if applicable.

Possible platforms where the technology will be used include the Medium Unmanned Surface Vehicle (MUSV), the Large Unmanned Surface Vessel (LUSV), and the Mine Countermeasures Unmanned Surface Vehicle (MCM USV).

In Phase III, the product will be validated, tested, qualified, and certified for Navy use in at-sea trials across a wide range of conditions as applicable for the relevant class of problem. Additional software testing will likely also be required to ensure that all applicable conditions can be tested even if they do not occur during at-sea test periods.

These solutions have potential for dual use in unmanned or minimally manned commercial ships or unmanned vehicles that would benefit from the automation of rapid response techniques to isolate.

REFERENCES:

1. Tidjon, Lionel N.; Frappier, Marc and Mammar, Amel. "Intrusion Detection Systems: A Cross-Domain Overview." IEEE Communications Surveys & Tutorials 21(4), 2019, pp. 3639-3681. <https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8735821>
2. Bringhenti, Daniele; Marchetto, Guido; Sisto, Riccardo; Valenza, Fluvio and Yusupov, Jalpliddin. "Towards a fully automated and optimized network security functions orchestration." 2019 4th International Conference on Computing, Communications and Security (ICCCS). Rome, Italy, 2019, pp. 1-7. <https://ieeexplore.ieee.org/document/8888130/>
3. Aminato, Muhamad E.; Zhu, Lei; Ban, Tao; Isawa, Ryoichi; Takahashi, Takeshi and Inoue, Daisuke. "Automated Threat-Alert Screening for Battling Alert Fatigue with Temporal Isolation Forest." 2019 7th International Conference on Privacy, Security and Trust (PST), Fredericton, NB, Canada, 2019, pp. 1-3. <https://www.springerprofessional.de/en/combating-threat-alert-fatigue-with-online-anomaly-detection-usi/17500622>
4. Silverajan, Bilhanan; Ocaik, Mert and Nagel, Benjamin. "Cybersecurity Attacks and Defences for Unmanned Smart Ships." 2018 IEEE Conferences on Internet of Things, Green Computing, and Communications, Cyber, Physical and Social Computing, Smart Data, Blockchain, Computer and Information Technology, Congress on Cybermatics. Halifax, NS, Canada, 2018, pp. 15-20. <https://ieeexplore.ieee.org/document/8726823>
5. Mancini, Federico, et al. "Securing Autonomous and Unmanned Vehicles for Mission Assurance." 2019 International Conference on Military Communications and Information Systems (ICMCIS), Budva, Montenegro, 2019, pp. 1-8. <https://ieeexplore.ieee.org/document/8842676>

KEYWORDS: Cybersecurity; Boundary Protection Capability; Unmanned Systems; Perimeter defense; Automated network security management; Machine Learning; ML; UxS

N211-059

TITLE: High Temperature, Low Dielectric Constant Ceramic Fibers for Missile Applications

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop advanced high temperature ceramic fibers exhibiting high strength, low dielectric constant, low loss tangent, high thermal stability, and high oxidation resistance for missile and projectile system applications.

DESCRIPTION: Missile components such as radomes and control surfaces are subjected to tremendous thermal stress during missile flight. Current missiles use high temperature metals for control surfaces and ceramics (such as silicon nitride or silica) for radomes. Future advanced missiles will require components with greater thermal shock resistance with properties such as those exhibited by ceramic matrix composites (CMCs). However, the only fibers available for incorporation into CMCs are fused silica ("quartz" fibers), Nextel aluminosilicate fibers from 3M, and Nicalon fibers. These fibers suffer from a limitation on service temperature, generally about 1000-1200°C for the oxide fibers, and 1400°C for silicon carbide fibers. In the past, there has been insufficient market potential to support commercial development of fibers for higher temperature service.

Higher temperature fibers are desired, with the capability of surviving 1500°C or higher. For radome applications, fibers with low dielectric constant and low loss tangent are needed. The desired values for dielectric properties, mechanical properties, and thermal properties depend on specifics of the radar system and overall weapon design, and can vary. There is no absolute limit for either, but the concepts are discussed in the reference by Walton [Ref 5]. Examples of possible compositions for high temperature, low-dielectric constant fibers include boron nitride (BN) and silicon nitride (Si₃N₄). Both types of fibers were produced experimentally in the 1975-1995 timeframe but are not available commercially. Availability of high temperature fibers possessing the desired combination of properties (such as high elastic modulus, low dielectric constant and loss tangent, and high strength to elevated temperatures) will enable the development of ceramic matrix composites with vastly improved high temperature properties compared to current CMCs.

Missile components needing these material technology improvements include radomes and control surfaces, since they tend to experience the worst of thermal heat stresses during high-speed flight. As such, the material solutions will need to have electrical properties conducive to radome functionality (e.g., low dielectric constant, low loss tangent) in addition to high thermal stability and high oxidation resistance necessary for both radomes and control surfaces.

Possible applications for the desired technology include tactical missiles, long range guided projectiles, and hypersonic vehicles.

PHASE I: Develop a concept for high temperature ceramic fiber materials that meets the parameters and applications in the Description. Establish concept feasibility of the requirements through analysis, modeling, and experimentation of materials of interest. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver notional full-scale prototypes that demonstrate functionality under the required service conditions including thermal and mechanical stresses. Use evaluation and testing to include high temperature mechanical tests, thermal shock tests, electrical tests, non-destructive testing, and microstructural examinations to show the prototype will meet Navy performance requirements. Develop and propose a Phase III Development Plan to transition the technology to Navy.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use in the STANDARD Missile program or other missile and/or projectile programs that could benefit from the material advancement. Support the manufacturing of the components employing the technology developed under this topic and assist in extensive qualification testing defined by the Navy program.

Potential commercial uses for high-speed radome and control surface performance improvements exist in the commercial spacecraft and aircraft industries and satellite communications.

REFERENCES:

1. Kamimura, Seiji; Seguchi, Tadao and Okamura, Kiyohito. "Development of silicon nitride fiber from Si-containing polymer by radiation curing and its application." Radiation Physics and Chemistry, Volume 54, Issue 6, June 1999, pp. 575-581.
<https://www.sciencedirect.com/science/article/abs/pii/S0969806X97003149>
2. Yokoyama, Yasuharu; Nanba, Tokuro; Yasui, Itaru; Kaya, Hiroshi; Maeshima, Tsugio and Isoda, Takeshi. "X-ray Diffraction Study of the Structure of Silicon Nitride Fiber Made from Perhydropolysilazane." American Ceramic Society Journal, Volume 74, Issue 3, March 1991, pp. 654-657.
3. Okano et al. US Patent US5780154A. Boron nitride fiber and process for production thereof.
<https://okayama.pure.elsevier.com/en/publications/x-ray-diffraction-study-of-the-structure-of-silicon-nitride-fiber>
4. Johnson, Sylvia. "Ultra High Temperature Ceramics: Application, Issues and Prospects." American Ceramic Society, 2nd Ceramic Leadership Summit, Baltimore, MD, August 3, 2011.
<http://ceramics.org/wp-content/uploads/2011/08/applicationsuhtc-johnson.pdf>
5. Walton, J.D. "Radome Engineering Handbook: Design and Principles." Marcel Dekker, Inc., New York, 1970. https://openlibrary.org/books/OL5077781M/Radome_engineering_handbook

KEYWORDS: Missiles; Guided Projectiles; Radomes; Thermal Shock; Missile Erosion; Hypersonics.

N211-060

TITLE: Human-Machine Interface for Directed Energy Weapons

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate an advanced display technology that maximizes operator performance for high energy laser weapons.

DESCRIPTION: The Navy has a long history of experience with radar, electronic warfare, and gun and missile weapon systems. Operator controls for these systems have historically been developed slowly over time in conjunction with advances in the system technology and in response to operational experience, simply adding new features to the existing displays. For example, current radar operator displays and controls evolved from the analog scopes and dials used to measure and adjust analog radar functions. As new radar features were added, displays and controls were added and the operators were trained to absorb, process, and respond to the additional information. The advent of digital and flat panel technologies caused an exponential growth in the amount of information about target detections and extracted target parameters that could be displayed, but the system designer still had a solid foundation of prior art to guide the evolution of the operator interface. This is equally true in commercial applications, for example, air traffic control radars and displays.

In contrast, directed energy (DE) weapons are being developed in technological leaps such that the human-machine interface (HMI) can no longer afford this type of deliberate evolution. From the outset, the DE operator will be inundated with tactical information, much of it requiring quick decisions and responses. The potential for operator overload is significant, and the display must be developed in a manner that supports how the operator uses the available information to provide the most efficient and effective display of data, thus reducing the potential for human error in lethal and non-lethal engagements. The commercial world provides few, if any analogies and provides no ready solution that meets the particular combination of demands placed on the naval warfighter during combat – especially in the use of a weapon system that has no non-military counterpart and no historical precedent. Furthermore, evolving threats and the insertion of new capabilities and tactics to meet those threats means that the DE console, and its interaction with the human operator, will not remain static over time. The HMI must accommodate the addition of new capabilities as well as updates to both software and tactics, and provide the flexibility for operators to hone their skills while exploring new operational concepts without the need for extensive re-training. The DE console must therefore incorporate technology that reflects the current state of the art in human cognitive science.

In particular, high energy laser (HEL) weapon, are unique in their capability and complexity. HEL systems incorporate elements of both sensors and weapons; are instantaneous; and have essentially unlimited range. Target cueing, de-confliction, atmospheric conditions, sensor coordination, resource

management, battle damage assessment, and multiple other operational considerations place unprecedented demands on system operators and on the displays and controls at their command. An integrated HEL operator display is needed that maximizes operator performance while mitigating operator fatigue and the potential for error.

From a hardware aspect, the HEL operator HMI is anticipated to utilize and be based on the existing shipboard combat system display console. This console features three large flat panel LCD color displays with touch screen capabilities available on at least one of the panels. The intent of this effort is not to design a new and dedicated set of console hardware – this would be contrary to the Navy’s goal of commonality and affordability. Neither is the goal of this effort to develop finished tactical code for deployment (validation and certification of tactical code is prohibitively expensive). Rather, the goal of this effort is to design an HMI display that is based on how the user gathers and employs information that complements the particular strengths of human perception and the decision-making processes. It should be noted that “display” in this context is not just a collection of graphical interfaces and data read-outs. The display technology required is a coherent theme of graphical elements, symbology, visual cues, real-time video, and textual data captured in an HMI style guide and demonstrated (with representative software) on surrogate displays. This includes the methodology that organizes and presents these elements in conjunction with operator actions and queries. The technology should optimize the human operator’s effectiveness and efficiency by making the interaction between the HEL weapon system as seamless and natural as possible, and enabling the operator to effectively process and employ the myriad of information available in the most effective means to achieve mission success. Therefore, acceptable solutions must be firmly grounded in the science of human cognition. Testing will consist of controlled and monitored execution of the HMI technology with human operators utilizing the surrogate display hardware. Final validation of the prototype will be demonstration of the HMI prototype on the surrogate display hardware, as witnessed by Government subject matter experts and program managers.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for an HEL weapon operator HMI as defined in the Description section. Demonstrate the feasibility of the approach based on the principles of modern human cognitive science and some combination of analysis, modeling, simulation, and evaluation of initial candidate display architectures and themes. Show that the proposed approach can be fully realized and demonstrated on surrogate hardware in Phase II. The Phase I Option, if exercised, will include the initial design specifications and format for the display style guide as well as a capabilities description of the prototype solution that will be delivered in Phase II.

PHASE II: Develop a prototype of the concept of the HEL weapon operator HMI technology that meets the requirements defined in the Description section. Demonstrate the prototype on surrogate computer hardware and displays (may require the synthesis of surrogate display inputs for example, video imagery). Further demonstrate the prototype through the development of non-tactical code that emulates the tactical displays. Update, finalize, and deliver the design specification that was initiated in Phase I along with the fully demonstrated style guide. Government subject matter experts and program managers will witness demonstration of the prototype technology on the surrogate display system.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. This may include evaluation of the final HMI implementation in tactical code on the tactical displays to validate compliance with the design specification and style guide; and may also include expansion of the style guide as additional data elements are incorporated in the HEL operator display in the future and as the display hardware receives normal updates.

Potential additional uses of the fundamental display technology developed under this effort include applications to highly complex and networked systems such as air traffic control, train dispatching, control centers for the electrical power grid, and wide-area security systems.

REFERENCES:

1. Endsley, Mica R. "Designing for Situation Awareness: An Approach to User-Centered Design, Second Edition." Boca Raton: CRC Press, 2011. <https://www.crcpress.com/Designing-for-Situation-Awareness-An-Approach-to-User-Centered-Design/Endsley/p/book/9781420063554>
2. St. John, Mark and Smallman, Harvey. "Staying Up to Speed: Four Design Principles for Maintaining and Recovering Situation Awareness." Journal of Cognitive Engineering and Decision Making 2, 1 June 2008, pp.118-139. <https://journals.sagepub.com/doi/pdf/10.1518/155534308X284408>

KEYWORDS: High Energy Laser Weapons; HEL; Directed Energy; DE; Human-Machine Interface; HMI; Tactical Displays; Human Cognition; Operator Performance for HEL

RT&L FOCUS AREA(S): Microelectronics

TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an advanced read-out technology that improves the detection of small targets with large, staring, infrared focal plane arrays.

DESCRIPTION: Focal plane arrays (FPAs) are used in narrow field of view (NFOV) sensors (i.e., cameras) to obtain high resolution images and in wide field of view (WFOV) sensors to surveil large areas of interest. In military applications, NFOV sensors typically benefit from powerful optics with high magnification and stabilized gimbal mounts that hold the camera on target and maintain a moving track. In this application, relatively small format FPAs can be used to image individual targets. In contrast, sensors used for persistent surveillance typically stare in a fixed direction to ensure that all possible targets within the field of view are detected. For staring sensors, the only way to increase resolution is to increase the size of the FPA since the magnification of the optics alone can't be increased without changing the angle of view. For WFOV staring sensors therefore, extremely large FPAs must be used to provide the maximum resolution possible. Not only does this drive up cost (FPA cost typically scales with size), it also introduces other design problems in the imaging system. In particular, large FPAs (with pixel counts in the millions) generate a huge amount of data. Not only is processing this data a challenge, but simply moving the image data off of the FPA to the image processor becomes problematic. This is especially so if the system operates at a high frame rate.

In staring sensors, a great deal of the image space does not appreciably change from frame to frame. Empty sky remains empty sky and even clouds, calm water, shoreline, and land features are static when compared to the fast changing features of the image. In typical image file formats, these constant pixels can be compressed, greatly reducing the file size. However, this isn't done until after the image data is read out from the FPA. Capture and read-out of the FPA image data is done by a dedicated circuit, the read-out integrated circuit (ROIC). The ROIC is tightly coupled to the FPA and it is the ROIC that detects and integrates the signal generated by each pixel in the FPA. Therefore, the ROIC largely determines the signal to noise (S/N) ratio, the optical dynamic range, and the frame rate of the sensor. Image data captured and output by the ROIC can be improved by post processing but the ROIC characteristics place a fundamental upper limit on the detection performance of the sensor system. A fixed dynamic range, uniform across the image plane, inhibits simultaneous detection of both extremely dim and intensely bright objects.

Commercially available sensors are subject to this constraint, which is why digital photographs often have areas that are "blown out" and other areas are so dark as to record no detail. This is accommodated for by adjusting exposure to exclude dim subject matter by biasing the sensor to preferentially capture the brightest part of the image. High dynamic range image capture compensates for this by taking multiple images. However, compensation is accomplished in post-processing and no acceptable real-time solution

is commercially available. Furthermore, a fixed frame rate, also uniform across the image and limited by the ability of the system to ingest the huge volume of data generated, inhibits the ability to detect and track small, fast moving, or rapidly fluctuating objects. In all such cases, it is “small” targets that are the most difficult to detect. Practical considerations limit the read-out of very large format FPAs to low frame rates. Coupled with the limitations of well capacity, this means that only a small percentage of the light in a given frame can be captured and imaged by a large format FPA. This results in a reduction in signal-to-noise that effectively “hides” low signature targets.

Optically small targets are not necessarily small in physical dimensions. A large target at great range appears small to the sensor. Such targets may also be unresolvable due to the FPA size and limitations in the imaging optics. In the limit, a detectable target may occupy as little as one pixel. Typically, these targets are also dim as compared to the surrounding image. However, extremely bright small targets cannot be ignored. Motion or fluctuation in intensity of the target further complicates detection. Therefore, multiple, simultaneous, unresolved targets of a few pixels or less, exhibiting large brightness ranges and moving or fluctuating in intensity, present a particular challenge to staring WFOV sensor systems – largely due to limitations in the ROIC. Yet it’s these targets that are most critical for the system to detect, track, and identify.

A better solution would be to dynamically adjust the read-out of the image to optimize detection performance of the FPA over small, selected, “windows” of interest – for example, over a 16 by 16-pixel area. Since targets may be fast moving and/or rapidly fluctuating in intensity, the selected window should track with the target and automatically adjust its size and integration time as the localized intensity, contrast, and target motion and fluctuation demand. Since the application envisions very large format staring FPAs that may contain multiple simultaneous targets of interest in the field of view, multiple independent windows (up to 40) are needed.

The Navy needs an innovative FPA read-out technology that automatically identifies and selects regions of interest in the overall image and then interrogates the pixels within that region to define and then dynamically adjust the capture of pixel data within that region for optimum detection. Furthermore, the identified regions of interest should be capable of moving with the target and adjusting in size to maintain the necessary target detection and tracking, thereby minimizing the amount of additional data output from the ROIC. The goal is to increase WFOV sensing in the mid-wave infrared (MWIR) band without significantly increasing sensor cost. Therefore, the solution should not demand the concurrent invention of a new FPA but should be compatible with at least one of the existing families of MWIR FPA technologies (minimum 1 Megapixel format and maximum 12 micron pitch). Validation of the prototype will be accomplished by testing the combined FPA and readout circuit against moving targets (either targets of opportunity or synthesized targets on an outdoor range). Successful demonstration will include detection and tracking of targets as small as one pixel where the target is so dim as to be at least 3 dB below the FPA’s normal dynamic range.

PHASE I: Develop a concept for an innovative FPA read-out technology that improves the detection of multiple small and hard-to-resolve targets as described in the Description section. Define the architecture of the read-out technology and identify and select a compatible FPA technology in the MWIR band (minimum 1 Megapixel format and maximum 12 micron pitch). Demonstrate the feasibility of the proposed approach including the ability to scale to large format (tens of Megapixel) FPAs and predict the ability of the concept to achieve the simultaneous detection of targets that exceed the read-out circuit’s inherent dynamic range and are undetectable at the read-out circuit’s native frame rate. Demonstrate feasibility by some combination of analysis, modelling, and simulation. Analyze and predict the impact of the technology on the volume of image data produced by the read-out circuit. The Phase I Option, if exercised, will include a device specification, initial process description, and test plan in preparation for device prototype development and demonstration in Phase II.

PHASE II: Develop, demonstrate, and deliver a prototype FPA read-out technology as detailed in the Description section. Demonstrate that the technology meets the requirements in the Description section. Demonstrate the technology by selection of and integration with a suitable MWIR FPA (minimum 1 Megapixel format and maximum 12 micron pitch). Additionally, demonstrate the combined FPA and read-out circuit by imaging scenes of suitable complexity that contain combinations of small, dim, bright, moving, and fluctuating (in intensity) targets. After performance testing, deliver two prototype sensors (read-out circuit, FPA, and supporting circuitry) as well as any custom software, specialized test equipment, calibration equipment, fixtures, and targets developed under this effort to the Naval Research Laboratory.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Government use. Assist in scaling and applying the design for specific sensor systems. Mature, ruggedize, and validate the prototype designs for application to Navy imaging systems and assist in the transition of the technology to those systems. The technology resulting from this effort will have application in the field of scientific imaging as well as in commercial products for security systems, law enforcement, and search and rescue operations.

REFERENCES:

1. Driggers, Ronald G., Friedman, Melvin H., and Nichols, Jonathan M. "Introduction to Infrared and Electro-Optical Systems, Second Edition." Boston: Artech House, 2012.
<https://us.artechhouse.com/Introduction-to-Infrared-and-Electro-Optical-Systems-Second-Edition-P1536.aspx>
2. Marcotte, Frederick, et al. "High-dynamic range imaging using FAST-IR imagery." Proc. SPIE 9071, Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXV, 90710E, May 29, 2014. <http://spie.org/Publications/Proceedings/Paper/10.1117/12.2053810>

KEYWORDS: Read-Out Integrated Circuit; Focal Plane Array; FPA; Staring Sensors; Wide Field of View Sensors; WFOV; Mid-Wave Infrared; Optical Dynamic Range

N211-062

TITLE: Nondestructive Detection of Flaws through Thick Polymers using Electromagnetic Imaging Technologies

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a wireless nondestructive testing (NDT) capability to inspect hull metal surfaces and assess hull-to-polymer bond health under thick polymer layers without polymer removal.

DESCRIPTION: There is currently no method for nondestructive testing (NDT) of metal health through thick polymers. Current methods for inspections through thick polymers involve destructive removal of sections of the thick polymer. Removal and replacement of these polymer sections involve costly (in labor, time, and materials) operations that generate hazardous waste. An electromagnetic imaging NDT method for inspections through thick polymers is needed to reduce lifecycle costs, improve accuracy of initial maintenance work scoping, and increase operational readiness by reducing emergent maintenance issues in-field that were not discovered during scheduled maintenance. Any solution designed herein must wirelessly transmit data from the electromagnetic imaging sensor unit to a remote device for user-analysis. The electromagnetic imaging sensor unit must weigh 15 pounds or less (including power supply).

The developed NDT system must conform with all Federal Communications Commission (FCC) regulations and deliver a signal-to-noise dynamic range that corresponds to a linear interpolation as a function of frequency between 80dB at 15 GHz and 100 dB at 25 GHz (the frequency range of interest) via either a single frequency, narrowband, broadband, or multi-band solution. The NDT system must detect and classify debonds of any separation distance, corrosion, water intrusion, and surface metal loss (due to damage) of 0.41" diameter or greater on a metal substrate through a thick polymer coating with a refractive index of 1.0.

NDT of a metal substrate through a thick polymer coating while maintaining sub-wavelength resolution has been a long-standing challenge for electromagnetic imaging technologies, such as Terahertz imaging or millimeter-wave imaging, operating at far-field distances from the signal source. At 15 GHz with $n = 1.0$, the diffraction limit (wavelength size) is 0.79", and at 25 GHz with $n = 1.0$, the diffraction limit is 0.47". Thus, for the designated frequency band of interest, the given 0.4125" at $n = 1.0$ feature detection requirement requires sub-wavelength resolution, far-field interrogation of the target. Far-field detection of features smaller than 0.4125" at $n = 1.0$ is also of interest if possible. Sub-wavelength resolution is possible with geometric super-resolution techniques, such as Multi-spectral Signal Characterization (MUSIC). Far-field super-resolution techniques exist, yet no ruggedized end-user solutions with suitable detector/classifier algorithms are available in the current market. The development of a commercially viable prototype is needed for Navy applications.

Current and near-future Navy preservation applications require fine-resolution detection and classification of metal substrate flaws through thick polymer preservation coatings to perform needed inspections for specific flaws of interest at reduced maintenance cost to the Navy due to repair labor and material from destructive inspection practices. As materials become thicker, they become more attenuating for electromagnetic waves. The materials of interest also become more attenuating with increasing frequency. Thus, to perform needed NDT imaging through the materials of interest, an electromagnetic imaging source is needed that operates along a linear trendline between 15 GHz at 80dB of dynamic range and 25 GHz at 100dB of dynamic range (i.e., 20 GHz at 90dB of dynamic range fits along that linear trendline). Solutions that use performance extrapolations outside of the 15-25 GHz range (along the same dynamic range trendline) are also of interest as long as they meet the required 0.41” minimum flaw detection size, are able to detect “kissing” debonds (defined as when two bonded surfaces break their bond but are still touching), and are in accordance with all FCC regulations.

Any prototype solution developed will also include commercial off-the-shelf (COTS) software tools that provide automated detection and classification of any flaws in the collected data as well as software tools to enable the Navy to incorporate Navy-developed automated detection and classification algorithms. These flaws include debonds (“kissing” and larger debonds), substrate metal corrosion, and water abscessed at the preservation-to-metal interface. The prototype solution should scan for flaws and give processed results as expeditiously as possible. The preferred solution provides results as close to real time as possible, is portable (1-person carry) with supporting equipment, and provides a graphical user interface that is easy to use and understand by a technician with sufficient training. Such training will be developed as part of this topic. The software may be developed in any modern programming language (i.e. Python, R, Rust, Julia, or an appropriate Javascript derivative) and should provide tools for the user to develop and include their own detection/classification algorithms to process the data in real time.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Define and develop a concept for a far-field electromagnetic imaging system with the capacity to meet the operational, frequency, dynamic range, minimum detectible flaw size, and automated detector/classifier requirements specified in the Description. Perform modeling and simulation to provide the initial assessment of concept performance and feasibility. Phase I Option, if exercised, would include the initial layout and capabilities description to build the unit in Phase II.

PHASE II: Develop and deliver a prototype based on the Phase I work and the Phase II Statement of Work (SOW) for demonstration and validation through a field test on a specified, Navy-developed test panel that is equivalent to testing on an in-service Navy asset under field conditions, showing that the prototype meets the performance requirements in the Description. Refine the prototype as required based on the results of the demonstration and validation process. Deliver the final prototype at the end of the Phase II, ready for field use by the Government. Deliver comprehensive instructions and documentation for prototype setup, operation, maintenance, and software SDK development to enable a user to make full use of the prototype.

It is probable that the work under this Phase II effort will be classified (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Assist the Navy in integrating the Phase II prototype into a field-use technology for Navy technicians. Provide a formal training curriculum (Level 1, Level 2, and Level 3) for Navy NDT inspectors to become certified in using this prototype for formal Navy NDT inspections. Update the training based on end-user feedback to the first version of the curriculum. Support Navy personnel to ensure all required software is approved for end-user use as well as testing, validating, certifying, and qualifying the prototype for Navy use.

Dual Use applications include other challenging electromagnetic imaging applications, such as assessing rebar health through concrete in structures, through-wall imaging, and contactless suspected bomb inspection.

REFERENCES:

1. "FCC Online Table of Frequency Allocations." Federal Communications Commission Office of Engineering and Technology, 07 May 2019 (revision). <https://transition.fcc.gov/oet/spectrum/table/fcctable.pdf>
2. "Radio Frequency Safety." Federal Communications Commission Electromagnetic Compatibility Division, 29 March 2013 (revision). <https://www.fcc.gov/general/radio-frequency-safety-0>
3. Liao, Wenjing, "MUSIC for Multidimensional Spectral Estimation: Stability and Super-Resolution." IEEE Transactions on Signal Processing, Vol. 63, No. 23, Dec. 1, 2015. <https://ieeexplore.ieee.org/document/7174562>
4. Ghasr, M.T.; Ying, M.P. and Zoughi, R. "Wideband Millimeter Wave Interferometer for High-Resolution 3D SAR Imaging." IEEE International Instrumentation and Measurement Technology Conference Proc., May 11-14, 2015. <https://ieeexplore.ieee.org/xpl/conhome/7137253/proceeding>

KEYWORDS: Terahertz imaging; electromagnetic imaging; millimeter-wave imaging; mm-wave; nondestructive testing; NDT; nondestructive evaluation; NDE; Multi-spectral Signal Characterization; MUSIC; synthetic aperture radar imaging; geometric super-resolution; SAR

N211-063

TITLE: Compact, Efficient, High Power Direct-to-Green Laser Source

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a highly efficient, direct-to-green laser source for detection of mine and mine-like objects in the Surfzone (SZ) and Very Shallow Water (VSW) regions, Increase the laser efficiency by more than 100% as compared to methods used today.

DESCRIPTION: Current laser sources are very inefficient due to the requirement to obtain the “Green” light from splitting an “Infrared” light source. The generation of green laser light via frequency doubling has typical conversion efficiencies that are ~50% for the process. In addition, the heat dissipation usually requires a method for dissipating the excess energy from the conversion process, upwards of 90%. Research into a relatively new technique of nano-particle doping of fiber lasers shows improved efficiency and power output over current fiber lasers and should be considered when proposing a solution.

In Stride Detect to Engage UAVs requires highly efficient laser sources to meet challenging size, weight, and Power (SWaP) requirements. A direct-to-green source would enable higher power at the same or less SWaP, enabling improved Area Search Rates and Time on Station. For the purposes of estimating SWaP requirements in proposals, the targeted air vehicle is similar to a Bell 407. The laser source will be enclosed in a to-be-designed externally mounted pod with an external diameter of 21 inches and external length of 110 inches. The SWaP will be shared with other sensors. The SWaP potentially available for the laser is 0.75 cubic feet, 60 pounds, and 700 Watts at 28 Volts Direct Current. However, it should be noted that one of the goals of the SBIR is to minimize SWaP. Desired output energy is approximately 500 millijoules at 532 nanometers. Trades will be considered between output energy and SWaP.

The laser shall take into consideration American National Standard Institute (ANSI) Z136.1, Safe Use of Lasers, and Code of Federal Regulations Title 21, Part 1040, Performance Standards for Light-Emitting Products. Other laser requirements, such as pulse width and repetition rate, are based on the chosen receiver. At this time, the Government does not have a receiver in mind but the laser should function with either a 2D Gated or a 3D receiver.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept and determine the feasibility of the concept to design a “direct-to-green” laser with improved efficiency over current “green” lasers. Demonstrate the feasibility of methods to manufacture “direct-to-green” lasers, which are manufacturable and able to be amplified in a highly efficient manner. Initial prototype validation of concept will be encouraged. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), the company shall develop and deliver a minimum Technology Readiness Level 5 prototype “direct-to-green” laser source suitable for follow-on Government testing (to include flight testing) and validation. The Government may test the laser in accordance with MIL-STD-810 test methods for low pressure (altitude), high temperature, low temperature, acceleration, and vibration for an airborne rotary wing environment. Additional tests may use MIL-STD-461 and MIL-STD-464 to verify electromagnetic compatibility.

Perform laboratory testing and fully characterize the system prototype. Parameters to characterize include bandwidth, pulse width, repetition rate, beam quality, output pulse energy, and output pulse intensity divergence and uniformity.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: The final product should be a ruggedized prototype direct-to-green sensor and software package that can interface with the Coastal Battlefield Reconnaissance and Analysis (COBRA) Sensor. Assist the Government to obtain flight certification on a NAVAIR UAV.

Other applications of blue-green lasers include oceanographic bathymetry, underwater sensing, LiDAR, and communications.

REFERENCES:

1. Baker, C.C.; Friebele, E.J.; Burdett, A.A.; Rhonehouse, D.L.; Fontana, J.; Kim, W.; Bowman, S.R.; Shaw, L.B.; Sanghera, J.; Zhang, J.; Pattnaik, R.; Dubinskii, M.; Ballato, J.; Kucera, C.; Vargas, A.; Hemming, A.; Simakov, N. and Haub, J.. “Nanoparticle doping for high power fiber lasers at eye-safer wavelengths.” *Opt. Exp.* 25, 13904, 2017. <https://doi.org/10.1364/OE.25.013903>
2. Mrázek, J.; Kašík, I.; Procházková, L.; Cuba, V.; Girman, V.; Puchy, V.; Blanc, W.; Peterka, P.; Aubrecht, J.; Cajzl, J. and Podrazky, O. “YAG ceramic nanocrystals implementation into MCVD technology of active optical fibers.” *App. Sci.* 8, 833, 2018. <https://www.mdpi.com/2076-3417/8/5/833>
3. Dinger, R.; Grundmann, F.P.; Hapke, C. and Ruppik, S. “High peak- and average-power, pulse shaped fiber laser in the ns-regime applying step-index XLMA gain fibers.” *Proc. SPIE 8961, Fiber Lasers XI: Technology, Systems, and Applications*, 896111, 7 March 2014. <https://www.dx.doi.org/10.1117/12.2033533>
4. The US Navy – Fact File. “AN/DVS-1 Coastal Battlefield Reconnaissance and Analysis (COBRA).” http://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=1237&ct=2

KEYWORDS: Direct to Green; Airborne Mine Detection; Detection of Ocean Mines; Compact Multi-Spectral Laser; Tactical Unmanned Air Vehicle Sensor; TUAV; Drifting Mines

N211-064 TITLE: Low Cost Deepwater Delivery Systems

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an innovative, low-cost method for delivering sensor payloads to specific locations or along specific trajectories for oceanographic, environmental, and biologic data collection in various depths of water.

DESCRIPTION: Oceanographic, biologic, and environmental data collection is needed to better understand the world's oceans and to support naval operations. A large portion of ocean data is collected using underwater sensors. Networks of underwater sensors are enhancing data collection and enabling an Internet of Things (IoT) approach to marine monitoring. Although marine sensors vary widely in design and application, there is a need for low cost deployment approaches for marine sensors.

Numerous methods exist for the deployment of underwater sensors. Some sensors are placed using cranes and winches from surface ships. Precise placement of the sensors at deeper depths requires sophisticated station keeping and tracking capabilities, and typically results in moderate to high deployment costs. Surface ship deployment of deep sensors using cranes and winches have costs that scale with platform size and mission duration. Costs can range from \$0.5M to \$10M depending on the sensor payload size and mission details. Remotely operated vehicles (ROVs) or deep submergence vehicles (DSVs) are also used to assist in sensor placement. These approaches typically require support from specialized surface ships and thus result in moderate to high deployment costs. Costs for ROV- and DSV-supported placement of deep water sensors typically range from \$2-3M to \$10-20M. Some sensors are deployed as a payload on an underwater vehicle. Example of vehicles used include underwater gliders, buoys, and unmanned underwater vehicles (UUVs). Underwater gliders are typically a low-cost combined sensor-vehicle approach using relatively simple vehicles and components and one- to two-person deployment operations that can be carried out from most any surface vessel. Sensor deployment as part of an underwater glider can result in costs as low as \$100K. However, most underwater gliders have limited payload capacity. UUVs vary greatly in size and also in payload capacity. UUVs have excellent payload delivery potential. However, most UUVs, especially those that can operate at deeper depths, have moderate to high purchase and operation costs. Deep-water sensor deployment via UUV typically incurs costs of \$500K to \$3M, depending on mission details. Floats offer a balance of low cost and moderate payload capacity, with costs ranging from \$100K to \$300K for some common systems. However, most float systems lack sufficient maneuverability to act as deeper depth sensor deployment systems.

At present, most existing methods for deployment of underwater sensors suffer from either high costs, low payload capacity, minimal maneuverability, or restrictions to shallow depths. Low-cost deep capable alternatives are needed.

The intent of this SBIR topic is to solicit novel ideas for low cost payload deployment in various depths of water. A system cost less than \$200K and deployment costs less than \$300K per deep water mission would greatly enable and extend deep water sensor-based activities in oceanographic, biologic, and environmental data collection. All concepts that can provide a low-cost means of deploying common sensor packages are of value and shall be considered. The following metrics are provided as general guidance, but solution concepts can deviate from these metrics as long as the solution provides an advancement in deployment operations or reduction in cost of established or future underwater sensors systems.

Potential payloads vary greatly in size, shape and weight. A target payload size is provided for purposes of design studies. Concepts that meet or exceed the target payload size will have strong potential for selection and transition. The target payload size is a dry weight of up to 100 lbs (45 kg), a net buoyancy ranging from 0 to 50 lbs (23 kg) negatively buoyant, and a total volume of up to 1000 cubic inches (16400 cubic cm). Although many sensor payloads are currently of cylindrical form factors, solution concepts should have moderate flexibility to accommodate both variations in payload shape and net buoyancy over the ranges provided.

The delivery solution shall be easily transported and stowed, ideally with minimal storage footprint and special equipment required. An on-deck footprint of roughly 3ft (1m) by 6ft (2m) would greatly expand surface ship deployment options and thus provide deployment cost reduction potential. Deployment of the delivery solution and payload will ideally require minimal support equipment. It is anticipated that two-person portable and deployable solutions will likely provide the greatest cost savings and have the greatest potential for transition to military and commercial use. Recovery of the delivery solution shall also be considered in comparing solution concepts. The recovery approach should minimize personnel and resources required. It is conceivable that some delivery solutions may be of sufficiently low cost and have a negligible environmental impact such that recovery of the delivery system is not required. Such solutions will have a favorable impact on logistics and will be rated accordingly.

The required placement performance of the delivery solution varies with different sensor payloads, but a placement uncertainty of 33ft (10m) is considered to have good transition potential. Placement at a fixed bottom location is considered a primary evaluation criterion. However, the ability to traverse a specified trajectory is also considered a valuable capability and will be considered when evaluating solution concepts.

It is desirable for the delivery solution to be able to operate in various depths of water. Depth capability will be a key factor for transition. Concepts should maximize depth capability. Concepts that can operate to full ocean depth will be applicable to the largest range of sensor deployment operations and will thus maximize transition potential.

Under many conditions, it can be advantageous to deliver a sensor payload to locations away from the deploying vessel in order to maximize sensor coverage while minimizing distance traveled by the deploying vessel. A delivery approach that can achieve accurate placement of a sensor over an operationally relevant horizontal distance from the deploying vessel has greater transition potential than a solution that can only deliver a payload to a location directly below the deploying vessel. Simple delivery concepts can be conceived which could provide horizontal standoff (range) from the deploying vessel. Concepts that can provide operationally relevant range (1km or greater) will have strong transition potential.

Cost is expected to be the most critical factor affecting transition. As discussed above, significantly reducing the operational costs of current delivery approaches will result in meaningful reductions in the

cost of underwater sensor delivery, and therefore any innovation with cost reduction potential is valuable. Solutions that can achieve low system costs, while providing the performance attributes above, will have significant transition potential. Cost savings potential are on the order of \$0.5 to \$3M+ per payload deployment and placement.

Phase II will feature prototype development and testing. The Navy will assist in developing a test plan that demonstrates and establishes the full range of performance characteristics of the solution. Potential test sites include the Atlantic Undersea Test and Evaluation Center (AUTEC), Pacific Missile Range Facility (PMRF), or an open ocean test site. Testing depths, environmental conditions, and test payloads shall be selected to fully exercise solutions in order to maximize demonstration value and enhance transition potential.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a conceptual design for a low cost deep-water delivery system that consists of the design, identified critical components, estimates of solution materials and manufacturing costs, and Rough Order of Magnitude (ROM) costs for transport, stowage, and deployment. Combinations of analysis, modeling and simulation may be required to establish solution feasibility. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a full-scale prototype system in Phase II.

PHASE II: Develop and deliver a prototype system and validate it with respect to the topic's objective. The prototype system shall consist of a vehicle functional and system diagram, a complete technical design package, vehicle integration plan, vehicle assembly plan, and vehicle test and evaluation plan that shows how to validate the prototype system performance. Evaluate the prototype based on payload capacity, delivery accuracy to a fixed bottom location for select depths and ranges, delivery accuracy along a desired trajectory for select depths, total system cost, and overall projected costs of transport, launch, and recovery. Aspects of Phase II testing will be dependent on the scope of solutions provided in Phase I.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use in the form of follow-on prototypes, using any lessons learned from the Phase II to improve the solution. Tailor the solution for deployment from specific vessels as required. Additionally, there is extensive commercialization potential for low cost deep-water delivery systems to support deep sea oil and mineral extraction as well as enable the sensors needed to regulate such industries. As such, Phase III will enhance the technologies to maximize alignment for delivery of sensors to support oceanographic, environmental, and biologic data collection, as well as resource management.

REFERENCES:

1. Wynn, R. B., Huvenne, V.A.; Le Bas, T.P.; Murton, B.J.; Connelly, D.P.; Bett, B.J.; Ruhl, H.A.; Morris, K.J.; Peakall, J.; Parsons, D.R.; Summer, E.J.; Darby, S.E.; Dorrel, R.M. and Hunt, J.E. "Autonomous Underwater Vehicles (AUVs): Their past, present and future contributions to the advancement of marine geoscience." *Marine Geology*, Volume 352, June 2014, pp. 451-468.
<https://www.sciencedirect.com/science/article/pii/S0025322714000747>
2. Verfuss, Ursula K.; Aniceto, Ana Sofia; Harris, Danielle V.; Gillespie, Douglas; Fielding, Sofia; Jimenez, Guillermo; Johnston, Phil; Sinclair, Rachel R.; Sivertsen, Agnar; Solbo, Stian A.; Storvold, Rune; Biuw, Martin and Wyatt, Roy. "A review of unmanned vehicles for the detection and monitoring of marine fauna." *Marine Pollution Bulletin*, Volume 140, March 2019, pp. 17-29. <https://www.sciencedirect.com/science/article/pii/S0025326X19300098>
3. Awan, K. M., P. A. Shah, K. Iqbal, S. Gillani, W. Ahmad and Y. Nam. "Underwater wireless sensor networks: a review of recent issues and challenges." *Wireless Communications and Mobile Computing*, Volume 2019, Article ID 6470359.
<https://www.hindawi.com/journals/wcmc/2019/6470359/>
4. Xu, Guobao; Shi, Yanjun; Sun, Xueyan and Shen, Weiming. "Internet of Things in Marine Environment Monitoring: A Review." *Sensors*, Volume 19, Issue 7, April 2019.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6479338>

KEYWORDS: Sensor payload delivery; Underwater Vehicle; Deep Ocean Delivery; Low Cost Navigation, Low Cost Underwater Systems; Low Cost Autonomy; Low Cost Deployment

N211-065 TITLE: Adaptive Narrowband Trainer

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an adaptive narrowband trainer that leverages artificial intelligence (AI), machine learning (ML), and real-world elemental playback data to detect, analyze, and classify real-world Passive Narrowband (PNB) signatures of submarine contacts.

DESCRIPTION: As adversary submarine forces field platforms that are increasingly capable and stealthy, the ability to detect these ships becomes ever more challenging. The ability to pace the threat with newer sensors and processing systems is part of the solution, but sonar sensor operators require better tools to effectively exploit the new sensor and system capabilities, specifically regarding narrowband detection and analysis. Relatively few training products address narrowband detection and analysis. Those narrowband training products that exist fail to leverage adaptive training, and Artificial Intelligence and Machine Learning (AI/ML). Existing interfaces to the latest tactical systems are limited, and existing narrowband trainers are not equipped for updates to represent emerging narrowband phenomena.

Sailor evaluation of PNB signals is particularly critical in successful Anti-Submarine Warfare (ASW) prosecutions. Depending on the sensor suite available, passive narrowband signals to be analyzed can be hidden across hundreds of beams of bearing and hundreds of frequency bins per line of bearing. Identifying specific signals associated with undersea threats in a timely manner is both a difficult skill to acquire and a skill that is highly perishable when use or effective training is not constant.

The Navy seeks an innovative narrowband trainer that adapts to emerging threats and maximizes accelerated learning. Essential elements of the trainer include a training or gaming platform that is both engaging and instructive. The trainer would ideally be accessed through the Moodle Learning Management System (LMS) resident on the respective shipboard tactical system, and capture operator performance data by leveraging experience API (xAPI) and the learning record store (LRS) resident on the tactical system. The trainer may also be accessed by ashore trainers such as the Submarine Multi-mission Team Trainer (SMMTT), the Multifunctional Instructional Trainer (MIT), the Applied Classroom (ACR) or the Virtual Operational Team Trainer (VOTT).

The trainer should be designed to include updateable real world elemental acoustic data provided by the Navy as a stimulus for the tactical displays the operator observes. The trainer should employ adaptive training techniques that will progress the student depending upon his/her level of knowledge and level of performance. In cases where the student is more proficient, that student should progress faster through the scenario and not be required to complete tasks associated with lower levels of knowledge or proficiency. The trainer should employ AI/ML to increase the challenge to the student according to the student's capabilities and to facilitate a rapid learning curve. The trainer should provide feedback to the student, both in the form of dynamic hinting during the scenario and a post exercise evaluation or after action

report that is referenced to an approved performance standard for better objectivity. The trainer should represent all display surfaces for data analysis and be able to represent the state of automation present in the build of sonar analysis software the sailor is tasked to use.

Additionally, the new training capability should leverage best practices in adaptive training. According to Metzler-Baddeley [Ref 2], “adaptive training used study time more efficiently than the chosen control conditions that is participants did not waste time studying items they already knew and were able to concentrate on items that required more training.” In turn, the trainer would maximize the operator’s time and increase training efficiency. According to Forsyth et. al [Ref 3], “adaptive learning recognizes the pace of student learning varies and provides instructors with the tools needed to relieve the time pressure of increased enrollment to reach students where they are in the learning process to enhance both student and teacher effectiveness.” Applying new adaptive learning approaches would benefit not only sonar operators at sea, but would also provide the schoolhouses with an additional resource for classrooms ashore. In addition, Sailor 2025’s Ready Relevant Learning initiative focuses on developing a “learning continuum where training is delivered by modern methods to enable faster learning and better knowledge retention at multiple points throughout a career.” Adaptive training would provide an excellent modern solution to this problem.

This SBIR topic addresses CNO’s desire to achieve “high velocity learning at every level” and supports Sailor 2025. This topic would seek to apply the best concepts, techniques and technologies to accelerate learning for individuals, teams, and organizations.

Additionally, this topic addresses current training requirements identified in the most recent Submarine Tactical Requirements Group Advanced Development Prioritized Focus Area letter specifically requesting “embedded training systems should be adaptive to the skill level of the trainee and ...real world elemental data should be capable of playback...allows for continuous learning on and off watch”.

Finally, this topic addresses current training requirements identified in the most recent AN/SQQ89 Advanced Capability Build Prioritized Focus Areas letter, to wit: “System training for operators should be readily available and delivered using modern training techniques and adaptive system training...”

Sailor evaluation of passive narrowband signals is particularly critical in successful ASW prosecutions.

Initial testing of this trainer can be accomplished at the company site given the prerequisite to provide a representative simulation of narrowband acoustic information that would be resident on a tactical system, tactical trainer or virtualized training simulator. Final testing and certification would be accomplished at the prime system integrator site or a site that contains a representative tactical system simulator with an installed Moodle Learning Management System. Initial testing would be conducted by the developer with Government/Government-designated representatives. Final testing and certification would be conducted by Government/Government-designated representatives in concert with Naval surface and submarine force active duty sonar operators.

Metrics used to assess the learning training capability will refer to learning gain, successful assessment of the adaptive training algorithm, and an acceptable usability score using the System Usability Scale (SUS). The Kirkpatrick Four-Level Training Evaluation Model will be used to objectively measure the effectiveness of training. The learning narrowband trainer must be able to integrate into the Moodle LMS as well as the learning record store (LRS) present in the learning architecture embedded in the tactical system of submarines and surface ships.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial

Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for an adaptive narrowband trainer utilizing AI/ML to teach and reinforce passive narrowband signature recognition. Demonstrate the concept feasibly meets all the parameters detailed in the Description through modeling and analysis. Also, demonstrate the concept can operate in the Moodle LMS, experience API (xAPI), and the LRS discussed in the Description. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype adaptive narrowband trainer for testing by ASW personnel in the Fleet. Demonstrate prototype performance through the required range of parameters in the Description. The Government or the company will provide facilities for testing and validating the prototype.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through system integration and qualification testing for the adaptive narrowband trainer prototype. Assist in transition and integration of the prototype to a future Advanced Processing Build (APB) Combat System with the potential integration including the Advanced Capabilities Build (ACB).

The narrowband training capability can be adapted to other technical fields that involve operator assessment of faint signals, found in electronic communications, medical diagnostic tools, and other engineering disciplines that deal with oscillating signals. Adaptive learning and AI/ML are innovative approaches that would be useful to the wider education and business communities as a whole.

REFERENCES:

1. Forsyth, B., Kimble, C., Birch, J., Deel, G. and Brauer, T. "Maximizing the Adaptive Learning Technology Experience." *Journal of Higher Education Theory & Practice*, 16(4), 2016, pp. 80-88. <https://articlegateway.com/index.php/JHETP/article/view/1992/1892>
2. Metzler-Baddeley, C. and Baddeley, R. J. "Does adaptive training work?" *Applied Cognitive Psychology*, 23(2), 2009, pp.254-266. <https://doi.org/10.1002/acp.1454>
3. "AN/SQQ-89(V) Undersea Warfare / Anti-Submarine Warfare Combat System." United States Navy Fact File, 15 January 2019. https://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=318&ct=2
4. Isson, Jean Paul and Harriott, Jesse. "People analytics in the era of big data: changing the way you attract, acquire, develop, and retain talent." Wiley & Sons, Inc., 2016. <https://www.worldcat.org/title/people-analytics-in-the-era-of-big-data-changing-the-way-you-attract-acquire-develop-and-retain-talent/oclc/991078367&referer>
5. Abraham, Douglas A. and Siderius, Martin. "Detecting Signals with Known Form: Matched Filters." ASA Press: Underwater Acoustic Signal Processing: Modeling, Detection, and Estimation, Springer, 2019. https://www.worldcat.org/title/underwater-acoustic-signal-processing-modeling-detection-and-estimation/oclc/1099924371&referer=brief_results

KEYWORDS: Narrowband Training Products; Adaptive Training Techniques; Ready, Relevant Learning; Artificial Intelligence; Machine Learning; Kirkpatrick Model.

N211-066 TITLE: Coupled Control of Expeditionary Remote Operating Vehicles (ROV) and Manipulator Payloads

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a coupled control system for optimal manipulator operation onboard an expeditionary class underwater Remotely Operated Vehicle (ROV) for greater performance.

DESCRIPTION: The United States Navy's Maritime Expeditionary Standoff Response program seeks to improve the capabilities of expeditionary Remotely Operated Vehicles (ROVs), which currently have limited manipulation capabilities. One of the improvements that is being implemented is the integration of multi-degree of freedom manipulator and end effector payloads that will enable these ROVs to perform increasingly complex tasks in the marine environment. ROVs currently in use operate with vehicle control systems that are independent from their payloads. During most operations using this paradigm, the ROV is able to adequately maintain its pose while the manipulator conducts its intervention tasks, operating with its own fully independent control system. For many tasks, an operator at a topside control station must intervene to alter the ROV orientation, communicating with a second operator of the manipulator/end-effector payload(s) who uses a second control station for operation of the manipulator. Work conducted under this topic will develop a fully integrated and coupled single control system for the combined ROV-manipulator system enabling the ROVs thrusters to provide additional degrees of freedom to the manipulator end effector. This approach will enable more fully optimized manipulation and reduce operator workload while performing complex manipulation tasks, and it will reduce the size and complexity of the ROV-manipulator system's control station as the ROV and manipulator will no longer require separate control interfaces.

A coupled control system will improve ROV and manipulator/end-effector payload system effectiveness and efficiency in performing complex underwater tasks, while concurrently reducing the size and complexity of legacy topside control stations, the requisite skill level and the quantity of system operators required for task accomplishment. Introduction of improved automation and coupled control of ROVs and payload control will reduce operator burden, training, and life cycle control costs for sustaining operational readiness of Maritime Expeditionary Standoff Response (MESR) systems.

To facilitate currently fielded systems as well as future developments, platform agnostic control systems architectures will be strongly preferred. Initial ROV platforms for demonstration and feasibility study should include either the VideoRay Defender or SRS Fusion vehicles that are currently in use with Expeditionary EOD units.

Initial feasibility studies and demonstrations may take advantage of open source simulation environments such as Open Source Robotic Foundation's Gazebo [Ref 3] or other suitable models that have sufficient fidelity to test and evaluate proposed solutions.

After a candidate coupled control system prototype is developed, it will be used to conduct a series of tasks that would currently be conducted with independent control systems. The differences between the current method and the prototype coupled control system will be quantified and recorded. Particular areas of interest to be explored during this experiment will be total system energy consumption, operator experience, manipulator function, and any other notable changes in capabilities and limitations of the system. This experiment will be conducted in an operationally relevant environment. Access to an operationally relevant environment for the experiment can be provided by the Navy, or the experiment may be conducted at a suitable location chosen by the selected company.

The control system developed under this program must employ a cybersecurity-compatible open architecture design to facilitate modular application to ROV platforms and manipulator payloads other than those for which it is specifically developed during this effort.

The Phase I effort will not require access to classified information.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a proposed control system concept and perform a feasibility study of that proposed concept. Feasibility will be assessed based on analytical results of the study.

Open source robotics simulation environments are acceptable for evaluating feasibility as are proprietary, custom, or in-house simulations, provided their underlying assumptions and constraints are sufficiently documented. For simulation-based experiments, the ROV and the manipulator system that is modeled should be representative of current Expeditionary ROVs and commercially available manipulator systems to the maximum extent possible. In areas where the model diverges from current systems, the necessary modifications to more closely align with fielded systems should be documented. At minimum, simulated models should demonstrate the fundamental concepts of the coupled control system well enough to evaluate their potential application to Navy ROVs outfitted with multiple-degree of freedom manipulator/end-effector systems. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), the company will develop a prototype of the coupled control system to be integrated onto an ROV-manipulator system that is representative of expeditionary class ROVs the Navy utilizes. Evaluate improvements against current systems through the conduct of a series of manipulation tasks in an operationally relevant ocean environment using both the coupled control system and the independent ROV and manipulator control systems. Quantify energy consumption requirements and characterize capabilities and limitations of path planning, operator experience, and overall manipulation functionalities of the proposed coupled control system in an operationally relevant environment. The Navy will provide access to operationally relevant environments for testing and demonstration if requested. Alternatively, selected companies may conduct tests and demonstrations in environments of their choice provided those environments maintain sufficient fidelity to fully evaluate candidate solutions.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. Ensure that the final product to be transitioned to the Navy will be a coupled control system for a Navy expeditionary class ROV with integrated manipulators; and will be designed and fabricated with a cybersecurity compatible open systems architecture that will enable modular application to systems other than

the prototype hardware/software on which it was originally developed, tuned, and demonstrated. Validate the system by carrying out a series of manipulation tasks relevant to Navy operations.

Coupled control for ROV/manipulator systems must demonstrate the potential to reduce operator workload and complexity of topside workstations, improve system energy efficiency, and improve the range of manipulation tasks that can be accomplished. Remote underwater manipulation is widely applicable beyond solely Navy applications, particularly in oil and gas, scientific, and academic communities.

REFERENCES:

1. Satja Sivec, et. al. "Underwater Manipulators: A Review." Ocean Engineering, Volume 163, 1 September 2018, pp. 431-450.
<https://www.sciencedirect.com/science/article/pii/S0029801818310308>
2. Barbalata, Corina; Dunnigan, Matthew W. and Petillot, Yvan. "Coupled and Decoupled Force/Motion Controllers for an Underwater Vehicle-Manipulator System." Journal of Marine Science and Engineering, Volume 6, Issue 3, September 2018. <https://www.mdpi.com/2077-1312/6/3/96>
3. Open Source Robotic Foundation's Gazebo—: <http://gazebosim.org>

KEYWORDS: Remotely Operated Vehicle; ROV; Manipulation; Expeditionary; Coupled Control; Autonomous Manipulation; Unmanned Systems

RT&L FOCUS AREA(S): Quantum Science

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop atomic inertial sensors that advance the state of the art in inertial navigation.

DESCRIPTION: The success of U.S. Navy missions depends on personnel and platforms having access to accurate and reliable position, velocity, attitude, and time information. Maritime platforms specifically need this information continuously to support safety of ship, weapons deployment, and network communications and geo-registration. The DoD developed Global Positioning System (GPS) to provide accurate, worldwide, all-weather, continuous position and time information to warfighters. As a result, GPS is the primary positioning and time source for maritime surface platforms. However, GPS is susceptible to interference and may not be continuously available. Consequently, in the absence of GPS, other technology is sought to provide positioning and timing information to meet mission support.

Many military platforms also usually deploy inertial navigation systems along with GPS. Inertial navigation systems are continuous, all-weather sources of position, velocity, and attitude information. Inertial navigation systems are not susceptible to interference in the same manner as is GPS. In addition, many maritime platform missions can be met with a military grade inertial navigation system. Inertial systems drift over and require periodic fixes to reset their position. Typically, an inertial navigation system will be corrected by fixes to GPS or some other fix source, such as a visual source, a radar contact, or some other navigational feature. In the event of a prolonged period of GPS not being available and no other usual sources being available, additional sources of position fixing are needed.

Inertial measurement sensors based on atomic interferometry solve the problem of sensor drift by providing measurements of acceleration and rotation with very low bias instability and random walk. This high performance is essential for GPS-denied inertial navigation, because position errors grow quadratically in time, proportional to random walk in the inertial sensors. Atomic interferometry uses wave-particle duality to measure accelerations and rotations as interference effects. These methods are precise because atoms have an exact internal electronic structure, which can be manipulated by electromagnetic radiation. The typical atomic interferometer is conceptually similar to a Mach-Zehnder interferometer, but with laser pulse induced Rabi oscillations enacting the behavior of beam splitters and mirrors. In laboratory settings, atomic interferometers have demonstrated super strategic-grade performance with long-term stabilities in the nano-g accelerometers and nano-radian/sec gyroscopes.

Atomic interferometers have previously been deployed on ships and airplanes with μg and $\mu\text{rad/s}$ sensitivity, but in general there are a few hurdles to deploying this technology in defense operations. This technology currently exists in the commercial market in the form of scalar quantum gravimeters (single-axis/1DOF accelerometers), but for the most part the technology has been funded and developed only for defense applications. In addition, navigation requires inertial measurement at frequencies well above 100

Hz, but atomic interferometer sensitivity decreases at higher frequencies, since atoms spend less time experiencing the acceleration or rotation. These devices must also have size, weight, and power, and cost (SWaP-C) low enough to be combined into a full inertial measurement unit (IMU) with gyroscopes and accelerometers along 3 spatial axes (for a total of 6 degrees of freedom). Other problems include the 2p-phase ambiguity, which limits the dynamical range of the atomic interferometer, wavefront curvature in lasers, and eliminating environmental noise.

An aspirational SWaP-C for a strategic-grade 6DOF IMU post-2020 is less than \$750,000, 40 liters, 250 Watts, and 40 kg. Previous efforts by DARPA include PINS/High Dynamic Range Atom Sensors and Systems (HiDRA II) and Chip-Scale Combinatorial Atomic Navigator (C-SCAN). C-SCAN sought to create a 6DOF strategic-grade IMU based on atomic interferometry within a 1 cubic inch and 1-Watt package. The result was the production of a 2DOF IMU with strategic-grade performance as an accelerometer and navigation-grade performance as a gyroscope. A related effort, Cold Atom Microsystems (CAMS) dramatically reduced the SWaP-C of atomic clocks relative to chip-scale atomic clocks. The technology sought should focus on either improving contrast to create a super strategic-grade IMU or on reducing SWaP-C to produce a chip-scale IMU with performance comparable to the PINS/HiDRA II 2DOF IMU.

The technology should target one of three areas: component development, strategic-grade IMU development, or 6DOF navigation-grade IMU development.

Component development should focus on R&D in the area of compact lasers, modulators, shutters, vacuum systems, or small-scale electronics. Lasers should have narrow linewidth (10 dB), or low wavefront curvature ($< 1 \text{ W}$) or pumpless. Electronics should be low power and ruggedized to support the other components.

Strategic-grade IMU development should improve the quality of existing atomic interferometer sensor technology by improving performance or reducing SWaP-C as defined hereafter. The ideal IMU achieves continuous-strategic grade measurements at an instability of 1 nrad/s, obtains continuous measurements at a high frequency ($> 100 \text{ Hz}$), eliminates background noise at the $\mu\text{rad/s}$ level, and maintains contrast in a dynamic environment. These goals can be supported through many-photon momentum transfer, co-sensor integration, rotation compensation with mirrors, continuous-beam atomic sources, atom-number squeezing, atomic gradiometry, wave-front control, or other innovative methods. A proposed atomic interferometer sensor should be able to reduce SWaP-C without degrading performance or to improve performance without increasing SWaP-C. An IMU should cover as many degrees of freedom as possible.

The technology will undergo an independent evaluation at a Government-provided facility to show it will function in a maritime environment. An IMU should function to specification for an indoor ship-motion simulation test. Components should maintain performance for realistic variations in temperature, pressure, vibration, ship-motion, and supplied power but not ruggedized for warship shock and environmental conditions. System navigation performance shall be tested without continuous GPS aiding for a period of at least 100 hours to measure long-term performance and stability.

Navigation-grade IMU development should produce a fully functional 6DOF based on currently existing atomic interferometer technology. Steps in this direction would be combining currently existing single-axis and dual-axis technology to produce a 6DOF navigation-grade IMU or developing ultra-low SWaP-C single and dual-axis devices, which will later be combined to form the full IMU. It is also possible to construct a 6-axis inertial sensor directly as was done by Canuel et al. in 2008. However, the final product should be field deployable in the marine environment using modular construction to fit through 24" doorway. The device should function on a dynamic platform with angular rates up to 0.3 rad/s, tilting of up to 60 degrees, and accelerations as high as 5 m/s² (with SWaP equal to or less than 1110 lbs., 600VA

max power draw with 600w max heat load, and 13 ft³ total volume, and functions in a shipboard environment. (0-95% humidity, 0-35oC). The technology sought will result in a resilient and accurate source of position and velocity information to U.S. Navy platforms. This information is needed to assure that platforms can meet mission need in the absence of GPS.

PHASE I: Develop a concept that characterizes atomic interferometry sensors that improves the inertial sensors for maritime platforms. Establish feasibility of an approach through analysis, modeling, and simulation to show the concept will meet the required parameters in the Description. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Design, develop, and deliver a prototype of the system described in Phase I. Demonstrate that the prototype meets the capabilities detailed in the Description during independent evaluation conducted at a Government-provided facility.

PHASE III DUAL USE APPLICATIONS: Assist the Navy in transitioning the technology to Navy use. The prototype will be tested on a maritime platform to demonstrate performance of the prototype and the associated system.

The technology will be highly valuable in the shipping industry and any at-sea situations where GPS is not always available and high accuracy is a requirement. If SWaP support is needed, aircraft and spacecraft are additional platforms that would benefit. R&D in supporting components will also enhance commercial electronics and the development of other next-generation sensors.

REFERENCES:

1. Kasevich, Mark and Chu, Steven. "Atomic interferometry using stimulated Raman transitions." Physical Review Letters, 67 181, 8 July 1991.
<https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.67.181>
2. Canuel et al. "Six-Axis Inertial Sensor Using Cold-Atom Interferometry." Physical Review Letters, 97 010402, 7 July 2006.
<https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.97.010402>
3. Mueller et al. "A Compact Dual Atom Interferometer Gyroscope Based on Laser-cooled Rubidium." European Physical Journal D., 53 3, 2009, pp. 273-281.
<https://link.springer.com/article/10.1140/epjd/e2009-00139-0>

KEYWORDS: Inertial Navigation Sensors; Cold Atom; Atomic Interferometry; Laser Pulse; Gyroscope; nano-g Accelerometer

N211-068

TITLE: S-Band Antenna System for Littoral Combat Ship Communications Relay

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a small, affordable, lightweight, and dynamic antenna system to be mounted on a remote aerial low-altitude relay that will enable Beyond Line-of-Sight (BLOS) communications between the Littoral Combat Ship (LCS) and the Mine Countermeasures (MCM) Unmanned Surface Vehicle (USV).

DESCRIPTION: The MCM USVs execute missions for LCS MCM Mission Package (MP). The network communication services between LCS and the MCM USVs are provided by the Multiple Vehicle Communications System (MVCS), which uses direct Line-of-Sight (LOS) communications in the S-Band – more specifically, in the 2.2 to 2.4 GHz frequency band. Results of a recent analysis performed at the Naval Surface Warfare Center Panama City Division (NSWC PCD) show that the Area Coverage Rate Sustained (ACRS) scores for the MCM USVs can be maximized by increasing the current maximum achievable range by a factor of 3-5. ACRS is one Measure of Effectiveness (MOE) typically used to evaluate MCM system performance, as shown in Reference 1.

Due to the antenna heights for LCS (90 ft for Independence variant, 65 ft for Freedom variant) and the MCM USV (18 ft), a 3x-5x increase in range using direct LOS communications is unrealistic, as it is severely limited by the radio horizon from the curvature of the Earth's surface. MCM MP data throughput requirements also effectively discard ground-wave propagation at lower frequencies as a possible solution, due to channel capacity limits. However, an intermediate relay node inserted between LCS and the MCM USV could enable a 3x-5x range increase and still meet MCM MP data throughput requirements without having to migrate to a different frequency band. This would allow having little to no change in communications equipment (i.e., radios, cables, amplifiers, and antennas) and configurations at the end nodes. Preliminary analysis and developmental test results have shown that an aerial relay at low altitudes – around 500 ft Above Sea Level (ASL) – should be sufficient to achieve the desired range increase. Not only would this be beneficial for the Navy, but also for the Marine Corps, who has shown an interest in developing a Long-Range USV (LR-USV) that can support its Expeditionary Advance Base Operations, as noted in Reference 2.

A currently existing prototype relay system uses an azimuth-plane omni antenna to establish a communications link with the MCM USV, and a gimbaled directional antenna that relies on actuators to physically steer the antenna's main beam towards LCS in the azimuth plane only – no direction finding in the elevation plane, as it always faces the horizon. Some of the concerns with the current prototype system include the following: Azimuth-plane omni antenna limits the communications range for the relay to MCM USV link and is susceptible to jamming from any direction; the gimbaled directional antenna can only scan as fast as the actuators allow, and is not expected to have good reliability or a long life cycle due to the actuators breaking down. These concerns open up the possibility of using other solutions,

such as switched array and phased array antennas, which should increase the life cycle by reducing/eliminating the need for moving parts, as well as allowing for faster scanning and/or tighter beamforming, so that directivity is maximized in any desired direction. Typical phased array antenna characteristics and design considerations are described in Reference 3.

The main objective of the technology is to produce a small, lightweight, and dynamic antenna system that can automatically beamform/beamsteer based on signal strength values reported from the radio. The antenna should be capable of handling fast beamforming/beamsteering to change beam directions between multiple end nodes. A secondary objective is for the antenna to implement null steering to avoid possible jamming sources.

There are multiple design constraints that should be observed, based on process modeling, operational experience, and optimization strategies:

antenna system – elements and switching/driving electronics

- should weigh less than 15 lbs
- should be able to achieve a gain of 15 dBi or more with a 20 dB minimum mainlobe-to-sidelobe ratio
- should have full 360-degree coverage in the azimuth plane and 40-degree coverage in the elevation plane centered at 10 degrees below the horizon
- should be able to handle 20 W average power (threshold) up to 40 W average power (objective)
- should cover the entire 2.2 to 2.4 GHz frequency band
- should not be more than 19 inches long and 15 inches in diameter
- Should have a response time of 20 microseconds or less
- should be environmentally sealed for protection against saltwater spray and continuous outdoor use
- in support of the secondary objective, the antenna should be able to create nulls at least 30 dB below the mainlobe and steer them towards jammers, while maintaining a communications link with the intended target/s.

Commercial antenna systems have been well developed for long-range communication systems in the S-Band, both for static and dynamic beam options. Switching/driving electronics for beamforming/beamsteering have also become robust. However, the challenge for this design, which necessitates innovative research & development, is being able to produce an antenna system with enough Effective Isotropic Radiated Power (EIRP) to close long-distance communications for link rates of 24 Mbps or more; minimizing Size, Weight and Power (SWaP) without exceeding cost constraints; minimizing response time for beamforming/beamsteering; and being able to survive harsh marine environments.

Any prototype antenna system developed as a result of this SBIR topic would be tested for its radiation characteristics – EIRP, directivity, beamsteering/beamforming, mainlobe-to-sidelobe ratio, mainlobe-to-null ratio – in a laboratory setup (anechoic chamber) during the Phase II effort. The optimized version of the antenna system would then go through environmental and electromagnetic interference (EMI) testing to applicable military standards (e.g., MIL-STD-810G and MIL-STD-461F). At the end of Phase III, a Seminal Transition Event (STE) will be conducted via an Over The Air (OTA) test in an operationally relevant environment onboard a relay system, with multiple active end nodes. The antenna system will be expected to not interfere with existing MVCS and endpoint certifications, and abide by established MVCS certification boundaries.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected

contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop an antenna concept that can meet the design constraints listed in the Description section. Establish feasibility by developing Computer-Aided Design (CAD) models that show the antenna concept and provide estimated weight and dimensions of said antenna concept. Feasibility will also be established by computer-based simulations that show the antenna array's beamforming/beamsteering capabilities are suitable for the project needs. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I and the Phase II Statement of Work (SOW), develop and deliver a prototype antenna system for test and evaluation. Test the prototype antenna system, first in a controlled laboratory environment, then in an operationally relevant environment, to determine its capability to meet all relevant performance metrics outlined in the Phase II SOW. Demonstrate the prototype system performance in both environments to the Government and present the results in two separate test reports. Use the results to correct any performance deficiencies and refine the prototype into a pre-production design that will meet Navy requirements. Prepare a Phase III SOW to transition the technology to Navy use. Prepare a Phase III SOW that will outline how the technology will be transitioned for Navy use.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to the LCS MCM MP relay system. Work with the Navy to integrate the antenna system onto the relay platform. Support test, validation, certification, and qualification of the system through environmental qualification testing, and with an STE at the culmination of the effort.

In the military/government sector, results from Phase II and Phase III for the relay platform antenna system can be leveraged to create variants of the antenna system for use on the MCM USV and LCS platforms, as well as demonstrate the MCM USV capabilities to perform missions at extended ranges for the Marine Corps LR USV concept. In the commercial sector, antennas with beamforming/beamsteering capabilities and anti-jam protection through null-steering could have potential for use in private communication systems set in urban environments, where spectrum congestion and interference – intentional or unintentional – can be prevalent issues.

REFERENCES:

1. Frank, David; Hogan, Kevin and Schonhoff, Shane. "Application of Model-Based Systems Engineering (MBSE) to Compare Legacy and Future Forces in Mine Warfare (MIW) Missions." Systems Engineering Capstone Project Report, SE311-132Open/Team MIW, Monterey, CA: Naval Postgraduate School, 2014, p. 359. <https://calhoun.nps.edu/handle/10945/44659>
2. Eckstein, Megan. "Textron's Common USV Ready for Production, Experimenting with Lethal Surface Warfare Payloads." USNI News, January 22, 2020 (Updated: January 23, 2020). <https://news.usni.org/2020/01/22/textrons-common-usv-ready-for-production-experimenting-with-lethal-surface-warfare-payloads#more-72882>
3. Mailloux, Robert J. "Phased Array Antenna Handbook, 2nd Edition." Artech House: Norwood, MA, 2005.

<http://twanclik.free.fr/electricity/electronic/pdfdone11/Phased.Array.Antenna.Handbook.Artech.House.Publishers.Second.Edition.eBook-kB.pdf>

KEYWORDS: LCS MCM MP; Mission Package; Littoral Combat Ships; Mine Countermeasures; MCM USV; Unmanned Surface Vehicle; Multiple Vehicle Communications Relay System; MVCRS; BLOS Communications; Beyond Line-of-Sight; ACRS; Area Coverage Rate Sustained; Phased-Array A

N211-069 TITLE: Medium Voltage Direct Current (MVDC) Partial Discharge and Space Charge Test Apparatus for Cable and Insulated Bus Pipe (IBP)

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop an affordable test apparatus and test method for detecting Partial Discharge (PD), measuring Space Charge (SC), and estimating remaining service life of Medium Voltage Direct Current (MVDC) cable and Insulated Bus Pipe (IBP) installed on naval ships, and to develop a Health Index and method to estimate remaining service life.

DESCRIPTION: An Integrated Power and Energy System (IPES) offers the potential to provide revolutionary warfighting capability at an affordable cost. An IPES utilizes integrated energy storage and power along with advanced controls to provide a distribution bus suitable for servicing highly dynamic mission loads and propulsion demands while keeping the lights on. Additionally, such a system can enhance survivability, reliability, and flexibility while providing new capabilities such as the ability to quietly maneuver solely on energy storage. Currently, IPES development is focused on a MVDC system evolved from the DDG 1000 1kVDC Integrated-Fight-Through-Power system combined with shared and distributed energy storage as well as advanced controls with active state anticipation data linkage between machinery and combat systems. MVDC IPESs will be used on future surface combatants to affordably improve warfighting capability to meet evolving threats over the ship's service life in an agile manner. As threat capabilities improve over the coming decades, the Navy is anticipated to rely more and more on high power, highly dynamic, and pulsed weapons and sensors. Because the need for generator synchronism is eliminated, MVDC is anticipated to be able to support these systems at lower cost, lower weight, and lower space requirements. Details on IPES are provided in the Naval Power & Energy Systems (NPES) Technology Development Roadmap.

As described in the NPES Technology Development Roadmap, ensuring service life of MVDC insulation is required for naval power and energy systems to support multiple future high power, pulsed sensors and weapons on future surface combatants. The ability to evaluate the health of MVDC insulation in installed cabling, insulated bus pipe (IBP) and their connections is critical to the successful implementation of MVDC and to avoid unplanned outages due to failed insulation systems. An important enabler to an MVDC system is a method to detect PD and measure the SC in the cable and/or IBP that has been installed onboard the ship during ship acceptance testing and periodically during the ship's service life (Threshold) or continuously while the ship is operational (Objective). SC and voids in insulation of cables and IBP and their connections that operate above 1 kV can result in PD that can rapidly lead to failure of the cable / IBP insulation system. Traditional methods used for alternating current (AC) systems are not effective on MVDC systems. Existing methods for detecting PD in AC cables assume clean sinusoidal waveforms and are not suitable for MVDC systems with high frequency voltage ripple (See Ghosh, et al. [Ref 4] and Montanari, et al. [Ref 5]). SC in particular is unique to DC systems. Without an effective means to measure the health of the insulation system, the insulation system must incorporate large safety factors, resulting in thicker and heavier cables. Due to cable thickness limitations resulting from bend radius considerations, this conservative approach will require great expense and more cables of lower current capability to be paralleled together.

The power quality of MVDC on the shipboard distribution system shall be assumed to be in accordance with the "Preliminary Interface Standard, Medium Voltage Electric Power, Direct Current". The test apparatus shall be compatible with nominal system voltages of 6 kV, 12 kV, and 18 kV and steady-state current ratings up to 8,000 amps. The test is anticipated to be conducted shipboard during the acceptance testing of the ship and prior to ship delivery to the U.S. Navy, and periodically during the ship's service

life (Threshold) or continuously while operational (Objective) to verify continued PD-free operation and to measure SC.

MVDC systems are increasingly being used or considered for military and commercial applications (e.g., microgrids, offshore energy, wind farms, cruise ships). The test apparatus and test method will apply to these applications as well.

Initially, the test apparatus and test method are anticipated to be used by NSWC Philadelphia personnel to verify PD-free operation and to measure SC. Eventually, shipyards and repair facilities are anticipated to be required to use the test apparatus and test method on applicable MVDC systems. The test method is intended to be formalized in a Test Method Standard in accordance with MIL-STD-962. If the objective is met, PD-free operation and SC measurements will be continuously monitored onboard ship. Estimated remaining life of the insulation system will be presented to the operator for maintenance planning.

PHASE I: Develop a concept for an affordable method for detecting PD and measuring SC in MVDC distribution systems onboard naval ships. This concept must include a system design of the test apparatus and a draft test procedure. Develop and document a health index and method for estimating remaining service life of MVDC insulation in distribution system cabling / IBP. Demonstrate the feasibility of the concept through modeling and simulation. Identify the technical risks of the concept. The Phase I Option, if exercised, shall include the design of experiments to address the technical risks and the procurement of long lead experiment articles and associated test equipment for execution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), conduct experiments to resolve technical risks. Employ the gained knowledge to develop a functional prototype of the test apparatus. Develop the test procedure, the health index calculation method, and the remaining service life estimate method. Validate performance of the test apparatus and test procedure initially through modeling and simulation, and then through testing.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. Develop the final production test apparatus suitable for use onboard naval ships and finalize the test method as a draft Test Method Standard in accordance with MIL-STD-962. Validate the performance of the production test apparatus and draft a Test Method Standard through testing. Deliver a test apparatus to the Government in accordance with the Phase III Statement of Work. Update and deliver to the Government the health index calculation method and the remaining service life estimate method.

REFERENCES:

1. Department of Defense, "Defense Standards Format and Content," MIL-STD-962, 5 November 2018." https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=36064
2. Doerry, Norbert. "Preliminary Interface Standard, Medium Voltage Electric Power, Direct Current." Naval Sea Systems Command, Technology Office (SEA 05T), Ser 05T / 002 of 16 January 2020. <https://search.dtic.mil> – search for AD1090170
3. Naval Sea Systems Command. "Naval Power & Energy Systems (NPES) Technology Development Roadmap 2019." <https://www.navsea.navy.mil/Resources/NPES-Tech-Development-Roadmap/>
4. Ghosh, Riddhi; Seri, Paolo; Hebner, Robert and Montanari, Gian Carlo. "Noise Rejection and Detection of Partial Discharges under Repetitive Impulse Supply Voltage." IEEE Transactions on Industrial Electronics, Vol 67, No 5, May 2020, pp. 4144-4151. <https://ieeexplore.ieee.org/document/8734896>
5. Montanari, Gian Carlo; Hebner, Robert; Morshuis, Peter and Seri, Paolo. "An Approach to Insulation Condition Monitoring and Life Assessment in Emerging Electrical Environments."

IEEE Transactions on Power Delivery, Vol 34, No 4., August 2019,
<https://ieeexplore.ieee.org/document/8636225>

KEYWORDS: Medium Voltage Direct Current; MVDC Partial Discharge; PD; MVDC Space Charge; SC; MVDC Insulation; MVDC Test Apparatus; MVDC Cable; MVDC Insulated Bus Pipe; IBP

N211-070 TITLE: Lightweight Diver Handheld Underwater Hydraulic Friction Stud Welding System for 5000 Series Aluminum

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a lightweight diver handheld portable hydraulic friction stud welding system and welding procedures for 5000 series aluminum to support sustainment and readiness for underwater ship repairs and salvage on the Littoral Combat Ships (LCS).

DESCRIPTION: The Navy has a need to wet weld aluminum studs on aluminum hull vessels to support underwater ship husbandry and emergency ship damage control, specifically on the LCS. Current underwater friction stud welding technology has been limited to carbon steel studs welded to carbon steel base plate material. Underwater friction stud welding using aluminum studs and base material has not been achieved commercially or within the Government. The equipment, whether pneumatic or hydraulic, is heavy and not adequately designed for safe use by divers performing underwater ship husbandry. A lightweight, diver friendly system that does not require special training or qualifications, and which could be used by Navy divers and Navy diving services contractors worldwide, is preferred for use in the field and during emergency ship damage control.

Research and development is required to further this technology in order to fill the Navy's current gap to perform underwater wet welding on aluminum hull vessels. Development of this technology will give the Navy the capability to wet weld aluminum studs to aluminum hulls, which can be used to perform underwater ship husbandry that would normally require dry-docking. This technology can also be used to attach cofferdams to perform underwater hull maintenance and repairs, something that is not possible currently. Performing repairs in the water significantly reduces overall maintenance and life cycle costs in comparison to dry-dock repairs. Additionally, the technology could be used to support emergency ship damage control efforts, such as patch attachments.

The concept design should allow for 1/2-inch minimum stud diameter and 3/8-inch minimum plate thickness. The weld head (actual equipment operated by the diver) should be as light as possible with a dry weight of approximately 25 pounds and be mechanically driven with no electrical or digital requirements to operate. The design concept should allow for the weld head to be operated by a 150ft minimum umbilical length attached to a hydraulic power unit (HPU). The HPU would be located on the surface and not be required subsea. The HPU can have electrical/digital requirements.

The technology, along with the welded stud coupons, will be tested against the qualification requirements of NAVSEA Technical Publication, S9074-AQ-GIB-010/248, Requirements for Welding and Brazing Procedure and Performance Qualification and Department of Defense Manufacturing Process Standard, MIL-STD-1689A, Fabrication, Welding, and Inspection of Ship Structure.

PHASE I: Develop a concept that will support fabrication of a prototype lightweight diver held hydraulic friction stud welding system capable of wet welding 5000 series aluminum (5086 stud to 5083 plate).

The feasibility of the concept shall be demonstrated as much as practicable by bread board bench testing and equipment prototyping. In addition, during this phase, the feasibility of welding 5086 studs to 5083 plate shall be demonstrated by welding coupons on a controlled environment and testing them by Non-Destructive and Destructive Test methods.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), a prototype system shall be developed and delivered to the Government for final test and evaluation. The system shall include the weld head (diver operated part of the system), umbilical, and hydraulic power unit. Perform initial evaluation of the system, including diver safety and ability to operate the weld head in the flat, vertical, and overhead positions, which can be in a shop environment without requiring any diving services. The system will also go through preliminary qualification testing based on a test plan developed by the Government IAW NAVSEA Technical Publication, S9074-AQ-GIB-010/248 and MIL-STD-1689A. Final test and evaluation will take place at the Navy Experimental Diving Unit, Panama City, FL.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. Deliver an operational system to the Government for qualification testing in accordance with NAVSEA Technical Publication, S9074-AQ-GIB-010/248, Requirements for Welding and Brazing Procedure and Performance Qualification and Department of Defense Manufacturing Process Standard, MIL-STD-1689A, Fabrication, Welding, and Inspection of Ship Structure. Provide all studs and plate material required for qualification testing. Provide all required training to safely operate the system.

After successful qualification, deliver the systems to the Navy's Emergency Ship Salvage Material (ESSM) program where they will be maintained ready for issue. Train ESSM personnel in the operation, maintenance, and overhaul of the entire system. Provide all drawings of the system to support fabrication, maintenance, and overhaul.

Not only will this technology fulfill the Navy's gap for wet welding aluminum studs to aluminum hull vessels, the technology can be transitioned to industry for use wherever aluminum studs are required to be welded either on the surface or underwater.

REFERENCES:

1. Murray, Robert and Couch, Jack. "Military and Commercial use of Underwater Friction Stud Welding." Underwater Magazine, Jan/Feb 2004. <https://app.aws.org/wj/archive>
2. Ratnayake; R.M. Chandima; Ytterhaug, H.O.; Bogwald, P. and Nilsen, S.T.R. "Underwater Friction Stud Welding Optimal Parameter Estimation: Engineering Robust Design Based Approach." Offshore Mech. Arct. Eng., Feb 2015. <https://doi/10.1115/1.4028466>
3. NAVSEA Technical Publication, S9074-AQ-GIB-010/248, Requirements for Welding and Brazing Procedure and Performance Qualification. http://everyspec.com/USN/NAVSEA/S9074-AQ-GIB-010_248_01AUG1995_51922/
4. Department of Defense Manufacturing Process Standard, MIL-STD-1689A, Fabrication, Welding, and Inspection of Ship Structure. http://everyspec.com/MIL-STD/MIL-STD-1600-1699/MIL_STD_1689A_1623/

KEYWORDS: Underwater Welding; Friction Welding; Friction Stud Welding; Aluminum Welding; Aluminum Joining Processes; Underwater Ship Repair

N211-071 TITLE: Nondestructive Evaluation (NDE) of Coated Multi-layered Fiber Reinforced Polymer (FRP) Components

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a method to detect defects in thick-coated Fiber Reinforced Polymer (FRP) and hybrid/integrated laminate construction.

DESCRIPTION: Thick coated Fiber Reinforced Polymer (FRP) laminate and hybrid/integrated laminate composites are used in critical component applications which demand that the component be free of defects of defined dimension and location. These defects include porosity, voids, delamination, moisture intrusion and defects in bond-line integrity. The configurations include FRP laminate (e.g., E-glass/vinyl ester, E-glass/epoxy, carbon/epoxy), FRP hybrid laminates, FRP/viscoelastic polymer, FRP/foam, and FRP/wood. The defects have the potential to interfere with acoustic performance and structural integrity and generally degrade ship performance.

Shipyards are often required to remove coatings to permit inspection or remove components all together to permit inspection from both sides. Both of these scenarios are time-consuming and negatively affect the sustainment costs and maintenance schedule. An inspection method is needed that can identify defects in composite components through thick (>1/4") coatings and from a single surface, thus increasing efficiency of inspections and decreasing ship impact during maintenance periods.

Current nondestructive testing technologies (i.e., visual inspection [VT], ultrasonic testing [UT], eddy current testing [ET]) are limited in their ability to:

- a) detect/quantify porosity in laminates/viscoelastic polymers
- b) detect bond-line defects
- c) detect water intrusion. The method to detect defects that the Navy seeks should be compatible with manufacturing, fabrication and in-service environments.

The method must be able to detect the range of identified defects and provide size and depth information, specifically, but not limited to:

- a) Delaminations/voids in FRP: 1/4" through 6" of material
- b) Porosity in FRP/viscoelastic polymers: >1% in a cubic foot of material
- c) Water intrusion: >5% by weight per cubic foot of laminate or FRP/core material
- d) Bond-line defects: 1/4" through 3" of material.

The method must be non-invasive (as opposed to destructive sampling), should demonstrate inspection time efficiency, and provide clear presentation of anomalies in the material, specifically in the selected regions of the material(s), such as a bond-line. Detection of disbonds in the FRP/coating bond-line is a highly desired outcome and an in-service inspection need. Detection of moisture in cored FRP sandwich

construction is another desirable feature. These components are often accessible from one surface only, particularly for in-service inspection and covered with thick coatings. A nondestructive testing method applicable to these requirements is not commercially available.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Define, develop, and demonstrate an inspection capability to detect and characterize the identified defects in representative sample material including porosity, voids, delamination, defects in bond-line integrity and moisture intrusion. Actual inspection capability shall be demonstrated (supported by analysis and/or simulation) for a variety of sample materials including coated and uncoated FRP laminate and FRP hybrid laminate composites. The Phase I Option, if exercised, will include documentation of performance demonstration and conceptual specification of a practical nondestructive testing system to be developed in Phase II.

PHASE II: Develop, demonstrate, and qualify a robust nondestructive evaluation system for detection and characterization of the specified defects in coated and uncoated FRP laminates, FRP hybrid laminates, FRP/viscoelastic polymer, FRP sandwich construction including foam and wood cored construction. These defects include porosity, voids, delamination, defects in bond-line integrity and moisture intrusion. The detection capability must be quantifiable through demonstrations with representative samples. . Note: NAVSEA will define the defect characteristics; and specify equipment characteristics appropriate for use during fabrication, installation, and in-service inspection. Representative equipment will be demonstrated.

Work with NAVSEA to determine representative standards for each of the targeted defects. NAVSEA will provide samples incorporating various defects for laboratory validation by the contractor.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: A portable, robust, efficient, and effective nondestructive inspection system for detection and characterization of defects in coated and uncoated FRP laminates, FRP hybrid laminates, FRP/viscoelastic polymer, FRP sandwich construction has a large potential commercial market. The capability validated in Phase II will translate directly into similar technical performance requirements in commercial market applications. As for Phase III transition, this work will benefit the following industrial applications:

- a) Reinforced rubber products for volumetric inspection. Applications include expansion joints in power plants and chemical processing facilities.
- b) Multi-layer armor, primarily for military applications (and some civilian law enforcement).
- c) Multi-layer composites for wind turbine blade application.
- d) Part quality of polymer composites for automotive and marine applications.
- e) Ceramic matrix composites, primarily for aerospace applications, both military and civilian.
- f) High density polyethylene (HDPE) joint inspections, specifically thermal butt fusion weld joining, for failure to properly fuse.

g) Fiber reinforced plastic (FRP) for absolute thickness and inter-layer disbond, specifically for FRP pipe and tank inspection in chemical processing, oil and gas as well as municipal infrastructure.

REFERENCES:

1. Multiple contributing authors. "American Society of Nondestructive Testing Aerospace Industry Handbook. American Society of Nondestructive Testing, 2014.
https://www.asnt.org/MajorSiteSections/Publications/NDT_Handbooks/Industry_Handbook_Aerospace.aspx
2. Schmidt, Karl, Editor. "The MW Compendium: Articles on Microwaves (Draft)." American Society for Nondestructive Testing, 2016. https://asnt.org/-/media/Files/Misc/CP-105-2020-Draft_20190430.ashx?la=en&hash=6380B0A53B0E18CC31E57F3735C4FB61AE6411B8
3. Schmidt, Karl, Technical Editor. "Field Service Microwave Inspection Experience in Dielectric Components, Materials Engineering." Materials Evaluation, American Society for Nondestructive Testing, 2016.
<https://ndtlibrary.asnt.org/2016/FieldServiceMicrowaveInspectionExperienceinDielectricComponents>

KEYWORDS: Nondestructive testing; bond-line integrity; bond-line imaging; composite integrity; composite volume imaging; Fiber Reinforced Polymer laminate; FRP

N211-072 TITLE: Automated Anchor Handling System

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a capability that will enable the planning and execution of autonomous anchoring evolutions scalable in operation for both Medium Unmanned Surface Vehicle (MUSV) and Large Unmanned Surface Vessel (LUSV) applications.

DESCRIPTION: The current state-of-the-art in anchor evolutions is manpower intensive requiring a user in the loop to both choose the location as well as execute and monitor the sequence of actions such as, but not limited to, the lowering and securing of the anchor. Innovations in process and method by which the Navy conducts anchor handling evolutions are required to ensure both safety and reliability while eliminating the required manpower necessary to enable truly autonomous operations for future unmanned surface vehicles.

The Navy seeks to develop an autonomous anchor handling system able to conduct a routine anchoring event with no human intervention. This includes planning for and selecting the anchoring location and then securely placing the anchor while continuously monitoring and adjusting as needed based upon the needs of the vehicle. Proposers will likely need to address not only the automation of the anchor handling machinery onboard the USVs, but the decision making autonomy that would provide the oversight and control of the event itself.

Multiple factors are considered when planning an anchorage location. These factors include: location, anchor to be used, depth of water, type of bottom, scope of chain to be used, drag and swing circles, and planned route, heading, and velocity profile in order to arrive at an anchoring location at 1 knot or less to pay out chain. Proposed anchor planning system concepts should be able to command the anchor handling equipment to place the anchor in a safe [Ref 5] manner upon arriving at desired anchorage point. After dropping anchor, the anchor planning system should identify if the anchor is dragging, the chain is tending across the stem (lead around the ship's bow), or if other ships are entering the drag and swing circles and take appropriate action. If the anchor planning or handling system determines the anchor is dragging, the planning system should take appropriate action, such as steaming to the anchor, directing the handling system to let out additional chain, or to weigh anchor and getting underway. The system shall autonomously manage and execute a plan on weighing anchor, including bearing and speed to ride the anchor chain, command the anchor machinery to lift the anchor, and provide confirmation to the vessel that it is safe to begin steaming. The system will need to include a troubleshooting function that indicates failure modes and system status as well as providing data to allow for the capability of remote operation.

An automated anchor handling system should be able to accept commands from a higher level system (autonomously as well as human in or on the loop) and be able to automatically handle, drop, and weigh

the anchor. Equipment shall be no smaller than Equipment Numeral U7 and no larger than Equipment Numeral U15 in Table 1, 2019 American Bureau of Shipping (ABS) Steel Vessel Rules (SVR) 3-5-1 (available at ww2.eagle.org – see p.346.) The largest anticipated anchor will weigh 1,590 kg, and will be a Stockless Bower type. Anchor chain is traditionally made up of 90 foot sections (or “shots”) of solid links. Each shot is joined to its neighbor by a single detachable link. The largest anticipated anchor chain diameter is 40 mm, using Chain Cable Stud Link Bower Chain. The anchor chain will be 900 feet long. The maximum force on the anchor and chain can be calculated from the preceding information together with Section 4-5-1 (pp. 414-418) of the ABS SVR. When the vessel has paid out the desired scope of chain, it is positioned so that a detachable link is on deck. This practice facilitates leaving the anchor behind in an emergency (“slipping anchor”) if the anchor windlass is inoperative and the vessel must get underway. Modifications to the traditional anchor, chain, and handling equipment in order to facilitate a fully automated process are to be considered within the design tradespace. Proposers should keep in mind the desire to have a scalable system that is Mobile Open Systems Approach (MOSA) compliant to allow for compatibility with future USVs. To ensure interoperability with planned and future USVs, solutions must also comply with the PMS 406’s Unmanned Maritime Autonomy Architecture (UMAA). UMAA establishes a standard for common interfaces and software reuse among the mission autonomy and the various vehicle controllers, payloads, and Command and Control (C2) services in the PMS 406 portfolio of unmanned systems (UxS) vehicles. The UMAA common standard for Interface Control Documents (ICDs) mitigates the risk of unique autonomy solutions applicable to just a few vehicles allowing flexibility to incorporate vendor improvements as they are identified; effects cross-domain interoperability of UxS vehicles; and allows for open architecture (OA) modularity of autonomy solutions, control systems, C2, and payloads. The Navy will provide the open standards for UMAA upon award of Phase I.

PHASE I: Develop a concept design for an anchor planning and handling system. The Government will provide the UMAA documentation in support of future Phase II proposal development. Deliver a concept design for reliable, safe, and repeatable operations, including any modeling and simulation, studies, or prototypes in support of concept risk reduction.

The Phase I Option, if exercised, will deliver a preliminary design of the concept, identifying the baseline design (hardware, software, support systems) and underlying architectures to ensure that the concept has a reasonable expectation of satisfying the requirements. See paragraph 4-5-1/7 on p. 417 of ABS SVR part 4 for Shop Inspection and Testing, and see paragraph 3-7-2/1 on p. 371 of SVR part 3 for Anchor Windlass Trials.

PHASE II: Develop and deliver a critical design prior to fabrication of the system or major system components for company testing. The system developed under the Phase II shall comply with MOSA and UMAA. The detailed design must meet the performance, cost, and schedule requirements. It will also identify the necessary interfaces, dependencies, and risks. After a successful Critical Design Review (CDR), develop a prototype(s). Testing and certification of the planning portion of the system will consist of simulation with the vessel of opportunity’s autonomy. Testing and certification of the handling portion of the system will consist of hardware-in-the-loop testing.

PHASE III DUAL USE APPLICATIONS: Successful anchor planning and handling systems will transition to either the MUSV program or the LUSV program. UMAA compliant anchoring planning software and anchoring systems for Navy USVs would have applicability to the commercial unmanned surface vehicles already widely in use further expanding their ability to adapt to their operational environment and conduct autonomous operations.

REFERENCES:

1. Baker, Clifford C.; Malone, Thomas and Krull, Russell D. "Survey of Maritime Experiences in Reduced Workload and Staffing." Carlow International Inc., Falls Church, VA, No. CGR/DC-292/99, 1999. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a372260.pdf>
2. Schank, John F.; Yardley, Roland J.; Riposo, Jessie; Thie, Harry J.; Keating, Edward G.; Arena, Mark V.; Pung, Hans; Birkler, John and Chiesa, James. "Options for reducing costs in the United Kingdom's future aircraft carrier (CVF) programme." Rand, 2005. <https://www.rand.org/pubs/monographs/MG240.html>
3. Pardo, Miguel Lamas; Carral Couce, Luis; Castro-Santos, Laura and Carral Couce, Juan Carlos. "A review of the drive options for offshore anchor handling winches." Brodogradnja: Teorija i praksa brodogradnje i pomorske tehnike 68, no. 3, 2017, pp. 119-134. <https://hrcak.srce.hr/181474>
4. Jiang, Huilue and Luo, Fei. "A Direct Torque Controlled Anchor System Design." 2015 International Conference on Intelligent Systems Research and Mechatronics Engineering, Atlantis Press, 2015. <https://www.atlantis-press.com/proceedings/isrme-15/18531>
5. Noel, John V. (editor) "Knight's Modern Seamanship 18th Edition." Wiley, 1988. <https://www.wiley.com/en-us/Knight%27s+Modern+Seamanship%2C+18th+Edition-p-9780471289487>

KEYWORDS: Automated Anchoring; Anchor Planning System; Anchor Handling System; Medium Unmanned Surface Vehicle; MUSV; Large Unmanned Surface Vehicle; LUSV; Energy Conservation

N211-073

TITLE: Intelligent Assistant for Anti-Submarine Warfare

RT&L FOCUS AREA(S): Machine Learning/AI

TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an intelligent assistant that improves active sonar detection, classification, and tracking and enables operators to maximize the potential of the tactical sonar suite.

DESCRIPTION: Navy Cruisers and Destroyers engaged in anti-submarine warfare (ASW) often use active sonar to perform detection, classification, and localization (DCL) of submerged threats. Active sonar employment involves numerous operational modes and settings that enable operators to adapt the sonar suite to the environment and current tactical goals or operational posture. This includes employment decisions such as changing the operational mode between pulsed active sonar (PAS) and continuous active sonar (CAS) as well as changing waveform and various other system settings. Operators must conduct sonar analysis of resulting sonar returns and interpret them based on the sonar settings and the environment.

Intelligent assistants are now commonplace in commercial industry but cannot be used in Navy systems. Similar tools do not exist to support operators of the tactical sonar suite. Effective employment of the sonar suite and analysis of the information it presents in complex and changing conditions creates a significant cognitive demand for operators. The Navy seeks to develop an intelligent assistant through leveraging advanced artificial intelligence (AI) technologies to support operators in this complex decision-making process.

An innovative intelligent assistant utilizing AI would bring together environmental information from the on-board tactical decision aid (TDA), in-situ, real-time assessment of the environment, and machine-learning algorithms to provide operators situational awareness regarding key parameters such as primary propagation path(s), bearing-dependent complications (such as sea mounts that might obscure threats), significant topology features into which a threat might retreat to minimize detection, best tactical waveforms, and situational best practices to enable operators to maximize the potential of the tactical sonar suite for the specific conditions present at that time and location. This assistant would have a significant analysis component, but would also have a direct interface with the operator through additional display elements and/or updates to existing display elements. In addition to realizing performance gains of at least 25% on active sonar detection, active sonar classification, active sonar tracking and end-to-end metrics relative to naïve employment of the system, this will enhance affordability by reducing the training time needed to realize a given level of operational performance. The technology developed will be tested using the IWS 5.0 Advanced Capability Build (ACB) step testing process. The seminal transition event will be validation by the Government and show the technology performs as required.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for an intelligent assistant utilizing AI that meets the requirements in the Description section. Show feasibility of the concept through analytical modeling, and developing and documenting the innovative algorithms, concepts, and architectures, and quantifying achievable performance gains. The Phase I Option, if exercised, will include the initial system specifications and a capabilities description to build a prototype in Phase II.

PHASE II: Develop and deliver a prototype intelligent assistant utilizing AI meeting the requirements in the Description for ASW. Demonstrate the prototype performance through the required range of parameters given in the Description. If needed, coordination with the Government will occur to conduct testing at a Government- or company-provided facility to validate the prototype's capabilities. Data sets from Cruise/Destroyer Hull Sonar and/or Littoral Combat Ship Variable Depth Sonar (LCS-VDS) will be used to validate the prototype's capabilities. The Government will provide the data.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use in ASW. Demonstrate and report on performance during laboratory testing. The prototype will be integrated into the IWS 5.0 surface ship ASW combat system Advanced Capability Build (ACB) program used to update the AN/SQQ-89 Program of Record.

This technology can be used in the weather and marine industries where automated assistants help identify tasks to be accomplished at certain timing.

REFERENCES:

1. "Anti-Submarine Warfare: Concepts of Operations for the 21st Century." TASK FORCE ASW, Navy Communications, 2017, pp. 1-5. <http://www.navy.mil/navydata/policy/asw/asw-conops.pdf>
2. D'Amico, Angela and Pittenger, Richard. "A Brief History of Active Sonar." Aquatic Mammals, 2009. <https://csi.whoj.edu/content/brief-history-active-sonar/index.html>
3. Serban, Floarea, et al. "A survey of intelligent assistants for data analysis." ACM Computing Surveys (CSUR), 45.3, 2013, p. 31. https://www.worldcat.org/title/survey-of-intelligent-assistants-for-data-analysis/oclc/942490000&referer=brief_results
4. Borrás, Joan; Moreno, Antonio and Valls, Aida. "Intelligent tourism recommender systems: A survey." Expert Systems with Applications, 41.16, 2014, pp. 7370-7389. https://www.worldcat.org/title/intelligent-tourism-recommender-systems-a-survey/oclc/5606588315&referer=brief_results
5. "AN/SQQ-89(V) Undersea Warfare / Anti-Submarine Warfare Combat System." United States Navy Fact File, 15 January 2019. https://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=318&ct=2

KEYWORDS: Intelligent Assistant; Anti-Submarine Warfare; ASW; Active Sonar Detection; Active Sonar Tracking; Sonar Employment; Sonar Analysis

N211-074 TITLE: Efficient Data Management to Improve Navy Maintenance and Ship Operational Readiness

RT&L FOCUS AREA(S): Cybersecurity

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an efficient and secure data management software application to use Condition Based Maintenance (CBM) and Reliability Centered Maintenance (RCM) to sustain, maintain and modernize ships, aircraft carriers, and submarines.

DESCRIPTION: The Navy operates ships that are technologically advanced and dependent on the effective application of information. The Navy needs a data analytics system that provides real-time ship performance and component-level data to affordably sustain the Fleet. Integrating the two initiatives of monitoring ship performance and securely transmitting ship performance data promises to transform the conduct of maintenance and the relationship of the ship and the shipyard.

Comprehensive understanding of a ship's current material condition is critical to maintenance performance. Traditionally, shipyard personnel assess the ship's material condition through ship visits and ship checks, ship system logs, the Consolidated Ships Maintenance Plan, previous work packages of the ship and other ships in its class, along with other sources of maintenance information. Visits are performed during the planning phase through scheduled ship visits, and just prior to start of a planned maintenance availability. However, as a preparatory method for planning an availability, this is insufficient for preparing the shipyard when execution of the work package reveals unanticipated maintenance problems, which increases costs and delays in schedule.

The Navy needs a secure data management system to share performance data between ships at sea and shipyards. Ships, aircraft carriers, and submarines operating at sea produce a tremendous amount of information. CBM, as a predictive concept, utilizes engineered maintenance standards based on objective historical conditions and predicted failure windows in order to determine when a component is due for maintenance. There is a concern that CBM has gone too far and disrupted the shipyard's ability to properly plan for large maintenance availabilities. In a data-managed environment, ship CBM and RCM parameters could technically flag ship system components based on performance criteria, generate lists of system and component status, generate prioritized task lists and automated work packages, and based on actual conditions, work lists could be generated and assigned to either the ship's force or the shipyard. Where CBM and RCM is automated, maintenance in a continuum and planning for large maintenance availabilities could focus on delivering capability to the ship, modernizing systems, structures and conducting major upgrades and alterations.

The Navy is currently testing the Enterprise Remote Monitoring (ERM) System to monitor ship systems and components while at sea. In effect, it will function as a sensor that monitors and collects vital performance data on a ship's hull, mechanical and electrical systems and components. When hosted in

such a way as to securely transmit data, in effect, the operators are connected with the maintainers for continuous maintenance support anytime and anywhere. This specific effort looks to leverage the ERM by establishing an architecture option for a software solution or suite of software that orchestrates the movement and processing of the data in such a manner that it can be scaled to advance capabilities.

The secure sharing of performance data through the ERM between a naval shipyard and a ship will deliver enhanced capability, resources and life cycle support enabling the integration of advances in technology, and a continuous planning process that aligns the current material condition of the ship with the capabilities of the shipyard. In a future state, the Navy could expand its planning and execution capabilities through simulation in a digital environment using all available information to create an instance-based digital twin of the ship, enabled by its digital thread, a record of its life cycle support, and sustainment activities. A digital twin for a ship can help the shipyard community identify, plan, track and test its repair needs in advance of an availability.

The production solution should be able to meet security requirements consistent with the DoD Risk Management Framework at the appropriate level. See NIST SP 800-53 for detail requirements. If a cloud solution is used, the system must also meet the requirements of the DoD Cloud Computing Security Requirements Guide at Impact Level 4. It is not necessary to demonstrate compliance during the prototype effort; however, details of compliance capability should be provided in the deployment plan.

PHASE I: Define and develop a concept for secure sharing of ship performance data between naval shipyards and ships, aircraft carriers, and submarines using the Navy's ERM System. The Phase I Option, if exercised, would include the initial layout and capabilities description to build a prototype in Phase II. Phase I testing should align with industry standards and best practices to ensure that investments drive value to the predictive maintenance community.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop a prototype for testing and evaluating the primary source data from a naval vessel and transmitted to a naval shipyard. This source data is expected to be sensitive and or classified, varied in type, and centrally available for further analysis, model building and visualizations to determine ship material condition and optimize planning activities for an upcoming major availability. Data interoperability and portability testing could include reports showing how historical source data matches the transmitted data for expected results, and demonstrate capability to efficiently implement business process and/or spatial data models for at least one identified system or asset as a starting point for replicating the physical world.

PHASE III DUAL USE APPLICATIONS: Assist the Navy in transitioning the technology for Navy use by working closely with the Naval Research Lab (NRL), NAVSEA, PEO Ships, Submarines and Carriers, and the naval shipyards. Implement the prototype for a secure means of sharing component and ship system performance data. Scale the technology to meet the demands of the Navy and so it can collaborate the dual use nature of the data construct with Transportation and Logistics, Energy, Manufacturing, and Telecommunications industries who use predictive maintenance or remote asset monitoring.

REFERENCES:

1. Carter, Troy. "Navy invents secure ship-shore data link for in-service engineering." Techlink, 1 Dec 2018. <https://techlinkcenter.org/navy-invents-secure-ship-shore-data-link-for-in-service-engineering/>
2. Eckstein, Megan. "Navy Embracing Quicker Software Development Model to Leverage New HM&E Data Collection." USNI News, 12 August 2019. <https://news.usni.org/2019/08/12/navy-embracing-quicker-software-development-model-to-leverage-new-hme-data-collection>
3. Werner, Ben. "Navy Looking for Better Ways to Share Data." USNI News, 20 June 2019. <https://news.usni.org/2019/06/20/navy-looking-for-better-ways-to-share-data>

4. Werner, Ben. "Navy Refining How Data Analytics Could Predict Ship Maintenance Needs." USNI News, 24 June 2019. <https://news.usni.org/2019/06/24/navy-refining-how-data-analytics-could-predict-ship-maintenance-needs>.
5. MAINTENANCE POLICY FOR NAVY SHIPS. OPNAVINST 4700.7M, 8 May 2019. <https://www.secnav.navy.mil/doni/Directives/04000%20Logistical%20Support%20and%20Services/04-700%20General%20Maintenance%20and%20Construction%20Support/4700.7M.pdf>

KEYWORDS: Secure Data Management/Sharing; Condition Based Maintenance; Reliability Centered Maintenance; Digital Twin; Digital Threading; Ship maintenance information design.

N211-075

TITLE: Active Nano Antenna Emulator for Electromagnetic Simulation

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a tabletop radar range leveraging high-resolution 3D printing and nanophotonics to serve as an optical emulator for complex electromagnetic (EM) systems.

DESCRIPTION: The Navy currently uses both simulation and measurement of a ship's Antenna- Radar Cross Section (RCS) to improve the design of new stealthy antenna on platforms and to ensure the accurate measure beam profile of the antenna in an environment. However, EM simulations are extremely challenging for large and complex objects that involve multiple constituent materials and fine details. Direct Antenna-RCS measurements may not be possible if the ship is part of an adversarial navy or if the ship is at sea. Currently DoD evaluates its antenna EM radiation beam profile using simulation and an actual measurement in anechoic chamber and field measurement. The process of doing such measurement is expensive and time consuming. It is also impossible to create a real-life scenario of EM reflection from other structure during actual operation of the system. This topic shall address such real-life scenarios with fabrication in nanophotonics and use nanophotonic radiation to characterize and simulate the EM scattering map without any anechoic chamber or infield measurement. This approach shall also reduce cost two orders of magnitude and time reduction from a year to a week.

Submarines may be subjected to high power laser beams and microwave radiation, which may damage optics and sensors in beam directors and periscopes. The Navy is seeking a technology that would demonstrate the possibility to accurately measure the radar antenna cross section & beam profile of large and complex antenna with a scaling factor of 100,000 under different environments such as sea surface with varying degrees of wave action and other EM radiation interference from adjacent masts on own-ship and nearby vessels. The advantages of this scaling approach is its versatility, and the possibility to perform fast, convenient, and inexpensive measurements on structures whose sizes prevent simulation, even with today's computers. This proposed technique shall also reduce cost (two orders of magnitude) and time (from a year to a week). This technique, based on the scale invariance of Maxwell's equations, leverages nano-scale 3D printing, as well as the availability of a variety of laser sources and high resolution detectors in 1 micron near infrared wavelength.

Interaction with Naval Information Warfare Systems Command (NAVWAR) personnel has revealed that one of the difficulties facing the development of new Navy platforms is optimizing the placement of antennas to minimize interference between antennas. The proposed method of using small-scale models and plasmonic-nanoantennas to simulate the EM field is estimated to provide a reduction in cost by a factor 1/150, and time by a factor 1/365.

Instead of needing a large anechoic chamber, the RCS measurements are done on a tabletop setup with highly detailed micron scale model. The models are illuminated with an external source of light, and the

scattered energy is detected with a charge couple device (CCD), similarly to a monostatic radar configuration. The direct 2D imaging of the scattered field allows us to identify the parts of the structure responsible for the RCS signal. This information is similar to what is obtained with an Inverse Synthetic Aperture Radar (ISAR) measurement but without the back projection computation. Measurement reliability shall also be demonstrated by comparing the results with a theoretical EM model for any shape under different environments.

The EM signatures of an antenna in a platform, such as a ship or a submarine, are of particular importance for the Navy since they allow the detection and identification of the antenna system and its performance on the platform. The vessel's active EM signature (EM Antenna), known as its radar cross section (Antenna-RCS), is proportional to the reflectivity of the structure and varies with relative spatial orientation of the vessel and the radar source. Minimizing this reflection improves the antenna performance of a radar system. The observed Antenna-RCS can also be used to improve the platform antenna performance.

The goal of the Nano antenna compact radar range program is to design and develop a tabletop radar-range system capable of measuring the EM signature of large and complex structures, including the antenna emission (gain) and their interference.

PHASE I: Provide a concept and determine the feasibility of the concept for the EM emission of a nanoantenna in the framework of tabletop radar range as well as simulations of antenna emission in the presence of simple geometrical shapes. Provide an assessment on how the dipole plasmonic nanoantenna will be manufactured using liftoff microstructuring technique as well as characterize the antenna emission direction. Liftoff lithography is a method of creating structures (patterning) of a target material on the surface of a substrate (e.g., wafer) using a sacrificial material (e.g., photoresist). It is an additive technique as opposed to more traditional subtracting technique like etching. The scale of the structures can vary from the nanoscale up to the centimeter scale or further, but are typically of micrometric dimensions. The nanoantenna will potentially be transferred on a relevant model and the gain compared to its original profile as well as the simulation.)

The Phase I Option, if awarded, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a prototype system for testing and evaluation based on the results of Phase I and the Phase II Statement of Work (SOW). Design, build, and demonstrate a prototype tabletop RCS system based on the proof of concept developed during Phase I. Demonstrate the ability to collect antenna emission measurements of a vessel of interest in near marine boundary conditions including realistic sea clutter. Fabricate a RCS system based on the prototype developed in the base period.

Field test the nanophotonic radar-range system at one of the Navy's facilities. Fabricate an active nanoantenna device that can be used to simulate the radar signal generated by the vessel's radar systems. The testing will consist of measuring the RCS of a specific model, of which the design will be provided by the Navy. A scaled model will be made using a nano-3D printer (not deliverable), and the RCS measurement will be measured using the nanophotonic radar-range. The result of the measurement will be a RCS polar plot that can be used by the Navy to compare with life scale measurement and/or simulation.

PHASE III DUAL USE APPLICATIONS: Assist the Navy in transitioning the technology to Navy use for antenna performance evaluation and location of the antenna for best performance. Army and Navy can use this technology to simulate the environment scenario to optimize the EM beam profile and its performance.

The nanophotonic radar-range system can be used for emulating the RCS of a large variety of platforms, from small boats like the 4M RX Rigid Inflatable with 12ft length to much larger vessels like the Gerald R. Ford class super carrier. The system can also be applied to all classes of submarines in near boundary conditions, including the Virginia and Columbia classes, as well as to measure the RCS of the AN/BVS-1 photonic mast. The nanophotonic radar-range system can find commercial use with any DoD branches and contractors desiring to understand the radar cross section properties of their platforms. This technique can be used during any phase of construction: development, production or refurbishing. It can also be used to acquire the RCS of structures that are inaccessible such as non-friendly nation platforms. For example, a contractor such as General Dynamics can use the system to better understand the RCS of the next generation of ships such as the USS Zumwalt. A contractor such as Raytheon can use the system to better understand the RCS of an enemy target to better detect, acquire, and follow that target with radar.

The technology shall also be used in telecommunication industry and TV to survey the antenna site before they actually do the field survey to optimize the reception and service broader spectrum customers. The system can find dual use application for the development of the 5G telecommunication to better understand the propagation of the signal in cluttered environment such as dense urban center. A Global System for Mobile operator can potentially use the nanophotonic radar-range system to optimize the location of their antennas to avoid dead signal zone.

REFERENCES:

1. Blanche, P.A. et al. "A 100,000 Scale Factor Radar Range." Scientific Reports, 7, 17767, 2017. <https://no-click.mil/?https://www.nature.com/articles/s41598-017-18131-1>
2. Blanche, P.A. et al., "A 300 THz tabletop radar range system with sub-micron distance accuracy." Scientific Reports, 8:14443, 2018. <https://no-click.mil/?https://rdcu.be/7SDy>
3. Novotny, L. and van Hulst, N. "Antennas for light." Nat. Photonics 2011, 5, 2, pp. 83-90. <https://no-click.mil/?https://www.nature.com/articles/nphoton.2010.237?message-global=remove&page=19>
4. Biagioni, P.; Huang, J.-S. and Hecht, B. "Nanoantennas for visible and infrared radiation." Reports Prog. Phys. 2011, 024402, p. 76. <https://no-click.mil/?https://iopscience.iop.org/article/10.1088/0034-4885/75/2/024402/meta>

KEYWORDS: Plasmonic; Nano-antenna; Antenna radar cross section; Antenna-RCS; electromagnetic; EM; NanoPhotonics; optical emulator

N211-076

TITLE: Autonomous Draft Determination

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop a concept for an autonomous or unmanned method to determine a vessel's draft accurately (Objective 1/16"; Goal 1/8") during required naval architectural experiments in various weather conditions with various hull forms to support on-time delivery of ships and submarines.

DESCRIPTION: Naval architectural experiments (i.e., inclining experiment and displacement check) are conducted prior to ship delivery to the fleet; avoiding schedule delays of these experiments by removing the small boat portion prevents delays of on-time delivery. The existing method can be hazardous and requires a manned small boat to collect draft readings at four locations (port and starboard; bow and stern) using a draft tube. Draft readings with draft tubes rely on personnel judgment due to reading the meniscus in the equipment that is not standardized between shipyards and may result in inconsistencies in draft readings taken. As much as practicable, the system developed should be used by shipyards to standardize the process of taking draft readings during naval architectural experiments. The system developed should be more efficient with at least a 50% reduction in time and/or labor (reduced schedule risk and reduced labor and travel costs), accurate (Objective 1/16"; Goal 1/8"), safer, and completely autonomous method to determine the draft of a vessel when conducting naval architectural experiments. The system should reduce schedule risk to on-time delivery and reduce costs associated with these experiments. The system developed will require fewer people (less cost) for the experiment, reduce risk of experiment delay due to the weather conditions that prohibit the small boat from going in the water to measure drafts (could mean up to ~100 people wasting 8 hours waiting for weather and ~20 people staying an extra night to perform the experiment the next day), and shorten the duration of the process in its entirety. The system should be operable in various weather conditions, including several feet of chop on the water surface and wind; and be able to determine draft on various hull forms including flared (e.g., carrier) or tumble homed (e.g., submarine) hulls and draft marks. Draft marks have a projected height of six inches but can be longer on the hull depending on the hull's curvature. This SBIR topic will contribute to reducing life-cycle costs (these experiments are performed throughout a vessel's life) while leveraging technology and data analytics. Observation of the draft marks and water surface could be recorded and the video could be converted to data to perform statistical analysis to obtain the average draft while the water surface perturbs. The existing method relies on personnel judgment to average out the perturbations and record an average reading, which is not objective, repeatable or standardized. Additionally, an autonomous system will allow the data collected to be stored and analyzed later whereas with the existing method, the reading is taken and a photograph is taken but they are difficult to verify or analyze later due to the angle of the photograph, lighting conditions, and timing of the photograph with wave action. These experiments require the vessel to be nearly complete and occur within days or weeks of delivery so any delays in accomplishing these experiments can impact on-time delivery of ships and submarines. There are approximately 20-25 experiments per year across the submarine fleet and 10-15 experiments per year across surface ships and aircraft carriers. These experiments are necessary to ensure the stability and safety of US Navy ships and submarines, are required by NAVSEA, and are applicable to submarines, surface ships, and aircraft carriers. The technological solution would likely be a device that the shipyards (both public and private) would procure. Utilizing an autonomous method to determine the draft of a vessel would reduce the set-up time and equipment needed, streamlining the process and reducing cost and schedule risk, and would not put personnel at risk (personnel have fallen into cold water and have almost been crushed between boat and pier).

PHASE I: Develop a concept for reading draft marks to sufficient accuracy (as stated in the Description) on submarines and surface ships during naval architectural experiments. The Phase I Option, if exercised,

will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a prototype based on Phase I work for demonstration and validation. Demonstrate the operation of the prototype to read draft marks with various hull forms and various weather conditions to sufficient accuracy as stated in the Description. The new system will be compared to results obtained using the traditional method by shadowing an experiment with the new system and/or using the ghost fleet in Philadelphia or a barge since they may provide easier access than an active Navy shipyard with commissioned boats. Deliver the tested device and associated software at the end of Phase II.

The prospective contractor may require access to U.S. shipyards (public and/or private) or other U.S. Naval facilities to demonstrate the capability. The system likely includes software so the software would have to meet applicable Navy requirements (e.g., IA, cyber, COTS).

PHASE III DUAL USE APPLICATIONS: Assist the Navy to integrate the Phase II-developed device and software into standard operating procedures at the shipyards and standards at NAVSEA for Fleet-wide use on submarines, surface ships and aircraft carriers.

The commercial shipping industry also performs inclining experiments to meet U.S. Coast Guard and/or classification society standards so U.S. or foreign shipyards may be interested in this device.

REFERENCES:

1. Tsujii, Takahiro; Yoshida, Hiromi and Iiguni, Youji. "Automatic draft reading based on image processing." *Optical Engineering*, 55(10), 14 October 2016.
<https://www.spiedigitallibrary.org/journals/optical-engineering/volume-55/issue-10/104104/Automatic-draft-reading-based-on-image-processing/10.1117/1.OE.55.10.104104.full?SSO=1>
2. Hirono, Kouhei; Sera, Wataru; Fuchi, M. and Kinzo, Inoue. "A Theoretical Study of the Draft Reading Device." *The Journal of Japan Institute of Navigation*, March 2006.
https://www.researchgate.net/publication/312351203_A_Theoretical_Study_of_the_Draft_Reading_Device
3. Powers, Earl. "Development and Use of a Tool to Accurately Measure Freeboards." SNAME, SMC-2019-55. <https://www.onepetro.org/conference-paper/SNAME-SMC-2019-055>
4. "Are Drones the Future of Marine Surveying?" Martek Marine, 9 Jun 2017. <https://www.martek-marine.com/blog/are-drones-the-future-of-marine-surveying/>

KEYWORDS: Navigational draft; draft marks; inclining experiment; displacement check; draft reading; draft analysis software.

N211-077

TITLE: Non-towed Broadband Acoustic Source

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Battlespace Environments

OBJECTIVE: Develop an innovative, acoustic source for operation from an 11-m unmanned surface vehicle (USV) producing the required output.

DESCRIPTION: Unmanned surface vehicle (USV) -based systems require lighter weight, lower drag, and smaller footprint products than their legacy counterparts [Ref 1]. There are currently a number of technology development efforts for various types of sensors and emitters that will be suitable for integration with a Fleet-class (11-meter) USV. However, many of these sensors and emitters are towed systems, which result in increased drag and fuel consumption, as well as reduced capability in shallow water and constrained waterways [Ref 2]. By eliminating the towed system from the USV, a reduction in towed system drag on the craft will result in increased endurance for the system while operating at the same speed. This will increase system capability by potentially increasing the coverage rate and allowing its use in shallower water and constrained waterways than current towed systems.

The U.S. Navy is seeking an innovative acoustic source capable of generating a broad range of outputs that would be mounted either above the waterline, within the hull and structure of the USV, or if a solution were sub-surface, the acoustic generator would be stowed above the waterline or within the USV hull-form until performing operations. The acoustic source(s) will be capable of being operated in very shallow water (20-40 ft), have low/no-drag (drag is constrained by the propulsive power used), and be non-towed or easily deployed/retrieved from the USV (less than 10 below the keel of the vehicle). Use of USV propulsion and hull systems, as well as legacy methods (e.g., mechanical cavitation, spark gap) is encouraged. The system must be lightweight (less than 400 lb.); require minimal electrical or propulsion power (less than 30 kw electrical power; Propulsive Power 125 hp); have a high acoustical power radiation (minimum 175 dB re 1 μ Pa @ 1m (1/3 Octave Band Level), frequency range of 10 Hz to 32 kHz, broadband white noise or multiple tones distributed over the required bandwidth, omni-directional or forward hemisphere transmission from one or several generators); and mitigate the effects of craft speed and its variations (12-18 kts, ± 5 kt speed variation). The acoustic generator will be autonomously activated by the USV's central command and control.

Offerors are encouraged to propose concepts that use waste energy from the USV (e.g., exhaust, propulsion noise, flow) that is amplified, controlled, and manipulated by the concept to generate the desired output. Legacy concepts (e.g., mechanical cavitation, spark gap) are also encouraged. Sets of transducers may not be viewed as novel technology for this topic unless of a new form or application, or offering unique capabilities in the operating environment is articulated. Offerors should note the likely presence of cavitation in the operation of their system and, if relevant, should address in their proposals how the system mitigates its effects, or uses it to a beneficial effect.

By eliminating towed items, the towed system drag to the Unmanned Surface Vehicle (USV) can be reduced by up to 50%. That savings will result in a lower fuel burn rate and an increased endurance. An increase in endurance will increase the capability of the USV and multiple payloads can be carried on the USV for multiple mission sets. Dragging these systems through the seawater increase the life-cycle cost based on the maintenance associated with the seawater environment. By removing the acoustic source from the water, the mean time before maintenance will increase which will reduce the life-cycle cost of these systems.

PHASE I: Develop a concept for an acoustic generator meeting the requirements in the Description. Feasibility of the concept for an innovative acoustic generator that meets the needs of the Navy as defined in the Description will be demonstrated by modeling and simulation, analysis, and/or laboratory experimentation, as appropriate. Acoustic output (frequency range, amplitude) will be the key quantitative performance parameter, with the level of speed independence, and size/weight/power being key system attributes. The effect of cavitation on the system performance, if relevant, should be clearly presented through the concept development and feasibility demonstration. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and fabricate a prototype acoustic generator based on the Phase I work and Phase II Statement of Work (SOW) for demonstration and characterization of key performance parameters, key system attributes, and objectives. At the end of Phase II, prototype acoustic generator components shall be tested according to Navy requirements. Testing of the key performance parameters and key system attributes will be an at-sea test over an acoustic range to verify that the task objectives were met. Based on lessons learned in Phase II through the prototype demonstration, a substantially complete design of the acoustic generator should be completed and delivered that would be expected to pass Navy qualification testing.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Navy use. The final acoustic generator product will need to conform to all specifications and requirements. A full-scale prototype will be operationally tested at sea on an acoustic range and certified by the Navy to be integrated with an USV for further performance testing.

REFERENCES:

1. Roberts, Scott D. "Stability Analysis Of A Towed Body For Shipboard Unmanned Surface Vehicle Recovery." Thesis, The Naval Post Graduate School, Monterey, CA, 2005.
www.dtic.mil/dtic/tr/fulltext/u2/a432512.pdf
2. "US Coast Guard. Boat Crew Seamanship Manual – Chapter 17: Towing." Department of Homeland Security, Washington, D.C., 2003, pp17.1-17.60.
http://www.uscg.mil/directives/cim/16000-16999/cim_16114_5c.pdf

KEYWORDS: Non-towed acoustic generator; unmanned surface vehicle (USV); acoustic frequency and amplitude; autonomous

N211-078 TITLE: Operator Analytics and Training Integration through Artificial Intelligence and Machine Learning

RT&L FOCUS AREA(S): Machine Learning/AI

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Develop an analytical toolset that mines sonar operator performance data via the tactical system along with training data gathered from the Moodle Learning Management System (LMS).

DESCRIPTION: The AN/SQQ-89 A (V)15 system collects a large amount of data from which it is possible to infer sonar operator performance data. The interactions that the operators have with the system can provide valuable insights into the fleet's training readiness. Applying Big Data mining techniques, methodologies, and analysis to the sonar system of the SQQ-89 would enable more relevant and real-time decision-making. The Chief of Naval Operation (CNO) has stated that there is a need to "Establish data-driven decisions as a foundation for achieving readiness in our warfighting enterprises. Lead Type Commands (TYCOMs), supported by Systems Commands (SYSCOMs), Budget Submitting Offices, and higher echelons will develop and maintain authoritative and accessible data for decision-quality information." By coupling artificial intelligence (AI) that mines the SQQ-89's operator performance data with learning analytics mined via machine learning applied to the Moodle LMS, decision-makers would possess the data necessary to make more informed decisions.

Additionally, the CNO desires to "Focus Navy efforts for fielding artificial intelligence/machine learning (AI/ML) algorithms on areas that most enhance warfighting, training, and corporate decisions." The current state of learning analytics used in the Moodle LMS include simple metrics such as activity completion and quiz/exam scores but lack the power to contribute to the understanding of student learning. An AI/ML toolset would provide the power necessary to measure an operator's abilities and determine areas for improvement quickly and accurately over traditional assessments. Currently no tools exist that can provide this capability. Obtaining this toolset would benefit the Navy by decreasing operational costs. Training should use study time more efficiently than the chosen control conditions so participants did not waste time studying items they already knew and were able to concentrate on items that require more training maximizing the operator's time and increasing training efficiency.

The Navy seeks an AI/ML toolset that captures data generated by operators interacting with the SQQ-89 system as well as the Moodle LMS hosted on the tactical system. The AI/ML toolset must also be able to format that data using "strategies to transform data into appropriate forms, to include smoothing, attribute construction, aggregation, normalization, and discretization (Susnea, pg. 74)." Such formatting would show patterns and provide additional insights into an operator's performance and behavior while using the SQQ-89.

In addition to formatting the data, the toolset must be able to perform descriptive modeling, which is a mathematical process that describes real-world events and the relationships between factors responsible for them. The toolset must also perform data analysis through predictive modeling, which is a process that uses data mining and probability to forecast outcomes. The toolset must also visualize the data in an easily digestible format to ease a decision-maker's ability to make better and more informed decisions quickly and with high confidence in the data.

Initial testing of the AI/ML toolset may be demonstrated at the contractor facility but a more robust evaluation of a fully developed toolset will be conducted using representative data gathered from a fleet test event, at a developer site such as the Lockheed Martin Anti-Submarine Warfare Laboratory in Manassas, VA, or from an appropriate Navy training facility such as Fleet Anti-Submarine Warfare

Training Center San Diego, CA. (FASW-TC). In order to properly evaluate the toolset, the test should include data from a team of sonar operators and their interactions with the SQQ-89 tactical system. Ideally, the interactions would include real-world or synthetic scenarios that span the detect-to-engage timeline. In addition to the data derived from the tactical system, a fully populated Moodle LMS comprised of training data from each of the participants of the sonar team would be preferred as the AI/ML toolset will need to uncover findings and correlations between the two sets of data.

Metrics used to assess the AI/ML toolset will refer to data quality, which can be defined as the degree to which a set of characteristics of data fulfills requirements. Examples of characteristics include: completeness, validity, accuracy, consistency, availability, and timeliness. The toolset must be able to apply big data analysis to the information present in the Moodle LMS as well as the learning record store (LRS) present in the learning architecture on the SQQ-89.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop a concept for an AI/ML toolset that mines data from the AN/SQQ-89A (V) 15 sonar system and Moodle LMS. Demonstrate the feasibility of the concept meets the parameters listed in the Description through modeling and analysis. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype of the AI/ML toolset and supporting architecture. Demonstrate at a Government- or company-provided facility that the prototype meets all parameters detailed in the Description. ASW personnel will conduct independent testing in the Fleet.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through system integration and qualification testing for the toolset prototype developed in Phase II. The AI/ML toolset prototype will be delivered to support a single transition event. Assist with the integration of the prototype into a future Advanced Capability Build of the AN/SQQ-89A (V) 15 Surface Ship Undersea Warfare Combat System.

The AI/ML toolset can be adapted to other technical fields including radio-frequency engineering and medical diagnostic tools. Big data and learning analytics are a relatively new field, but an architecture that allows adapting to different learning and training domains would be useful to the wider education and business community.

REFERENCES:

1. Harindranathan, P. and Folkestad, J. "Learning Analytics to Inform the Learning Design: Supporting Instructors' Inquiry into Student Learning in Unsupervised Technology-Enhanced Platforms." *Online Learning*, 23(3), 2019, pp. 34-55.
<https://files.eric.ed.gov/fulltext/EJ1228819.pdf>

2. Yang, Nan, et. al. "Data-Driven Modeling of Engagement Analytics for Quality Blended Learning." *Journal of E-Learning & Knowledge Society*, 15(3), 2019, pp. 211-225. https://www.researchgate.net/publication/336578777_Data-Driven_Modeling_of_Engagement_Analytics_for_Quality_Blended_Learning
3. Richardson, John ADM. "A Design for Maintaining Maritime Superiority 2.0, 2018. <https://news.usni.org/2018/12/17/design-maintaining-maritime-superiority-2-0>
4. Susnea, E. "How Big Data Analytics Will Reshape e-Learning?" *E-Learning & Software for Education*, 4, 2019, pp. 72-76. <https://doi.org/10.12753/2066-026X-18-225>

KEYWORDS: Sonar Operator Training; High Velocity Learning; Big Data Analytics; Artificial Intelligence; Machine Learning; Moodle LMS

N211-079 TITLE: Enhanced Situational Awareness Through Smart Geospatial Comparative Analysis

RT&L FOCUS AREA(S): Machine Learning/AI;General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments; Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop geospatial analytical algorithms to increase speed and alignment to kill chain requirements, in support of a Common Operational Picture (COP). Develop a smart comparative analysis capability to manage data types associated with both geospatial and non-geospatial representations using advanced analytics such as Artificial Intelligence (AI) and Machine Learning (ML) algorithms.

DESCRIPTION: The U.S. Navy requires greater speed of analysis in support of Kill Chain requirements for greater assessment of the environment, positive Identification of threats, and predictive capability to meet growing threat challenges in theater. In order to meet these growing demands, the development of robust technologies for smart geospatial analytics, using modern big data analytics, is needed. Smart geospatial analytics include separation of data and styling information, robust pluggable presentation analytics, and tabular representations. These analytics will feed into a COP for the warfighter, headed by the Maritime Tactical Command and Control (MTC2) system.

The MTC2 system is the Navy's next generation command and control platform providing modernized, robust, secure, integrated, and interoperable network-centric capabilities. MTC2 will replace the legacy planning and decision aid systems and provide a COP in a geospatial display to visualize an operational environment to maintain Command and Control (C2) Situational Awareness (SA).

The Command and Control Acquisition Program Office, PMW 150, currently fields the Global Command and Control System Maritime (GCCS-M) to support COP representation. The current technology is extremely dated and only provides tracks on a map for viewing with some overlays. Modern, state-of-the-art technologies are providing greater depth and analysis geospatially to consumers.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVWAR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Conduct a study to determine optimum algorithms to perform advanced analytics on geospatial and non-geospatial data to include AI and ML algorithms, and semantic reasoners. Identify the

developmental issues and formulate the methodology to include validation concepts which are technically feasible and achievable. The algorithms should be able to ingest geospatial and non-geospatial data to deliver renderings and visually present the data in multiple ways.

Describe the technical solution (i.e., software) based on the investigations and technical trade-offs. For the identified technical solution, develop the Phase II Project Plan to include a detailed schedule (in Gantt format), spend plan, performance objectives, and transition plan for the identified Program of Record (PoR).

Note: The Navy will provide samples of geospatial and non-geospatial data will be provided in Phase I to support an accurate feasibility study.

PHASE II: Develop a software prototype that is able to ingest various data sources and types, including textual and abstract such as Joint Message Handling System (JMHS) for textual and map representations for abstract data types; render geospatially; and evaluate the renderings with algorithms identified in Phase I. The software prototype will be deployable and used for concept validation allowing users to interact under operational condition. The prototype must run in a DEVSECOPS environment, gathering data from the users to feed into requirements for the Program of Record in order to validate concepts.

Provide insight into visual representations that can assess renderings, formulate understanding and provide the information directly to the user. Investigate themes like Semantics for incorporating attribute and computed values within filter criteria, provide dynamic filtering and linkback to external data sources, and automated drill down and queries based on user history. Provide a visualization environment that aligns with using Esri tools, such as the Commercial Joint Mapping ToolKit (CJMTK), and that is malleable to the warfighter's needs and learns from behavior.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Conduct further testing of the prototype on experimentation venues, such as Trident Warrior. Integration will be conducted by NIWC Pacific/Atlantic engineers. Initially, the technology will reside in the C2X environment being developed and fielded for test and evaluation. Once completed, integrate the technology into the existing MTC2 Configuration Management (CM) environment for inclusion in the MTC2 normal release update schedule to provide the warfighter the capability to have information analyzed continuously as the representation changes in the COP. The Smart Geospatial Comparative Analysis will provide significant increase in speed of understanding and will allow decisions to be more informed and analyzed to support the Kill Chain process. Commercially, these capabilities can be applied to current Geospatial Information Systems (GIS) to increase capability for industry use.

REFERENCES:

1. "NWP 3-56 COMPOSITE WARFARE: MARITIME OPERATIONS AT THE TACTICAL LEVEL OF WAR." <https://apps.dtic.mil/dtic/tr/fulltext/u2/a575608.pdf>
2. "NTTP 3-32 Navy Tactics Techniques and Procedures." [www.navybmr.com/study-material/NTTP_3-32-1_MOC_\(Apr_2013\).pdf](http://www.navybmr.com/study-material/NTTP_3-32-1_MOC_(Apr_2013).pdf)
3. "NWP 3-32 MARITIME OPERATIONS AT THE OPERATIONAL LEVEL OF WAR." <https://docplayer.net/44980043-Maritime-operations-at-the-operational-level-of-war-nwp-3-32.html>
4. "JP 3-32 COMMAND AND CONTROL FOR JOINT MARITIME OPERATIONS." https://fas.org/irp/doddir/dod/jp3_32ch1.pdf

5. “JP 3.0 DOCTRINE FOR JOINT OPERATIONS.” <https://docplayer.net/17806770-Joint-publication-3-0-doctrine-for-joint-operations.html>

KEYWORDS: Geospatial; analytics; AI; ML; Enhanced situational awareness; SA; comparative analysis; Common Operational Picture; COP; Maritime Operations

N211-080 TITLE: Wideband Interference Suppression for Dynamic-range OptiMization (WISDOM)

RT&L FOCUS AREA(S): Networked C3; General Warfighting Requirements

TECHNOLOGY AREA(S): Electronics; Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop digital and/or analog military HF (2 MHz to 30 MHz) wideband interference suppression system to yield significant improvements to SNR (>10 dB) and dynamic range (20+ dB).

DESCRIPTION: Battle Force Tactical Network (BFTN), AN/USQ-195(v) system provides tactical Radio Frequency (RF) networked communications for the Navy's afloat, airborne, ashore, and submerged U.S. Navy forces. BFTN currently transports critical Command and Control (C2) data with rates of 19.2 kbps over HF at up to 200 nm and 64 kbps over Ultra High Frequency (UHF) at up to 20 nm. BFTN is undergoing modernization, called BFTN Resilient Command and Control (RC2) System Enhancement, (BRSE), which will result in a significantly more capable system with a new waveform, Robust Communications for Challenging Environments (RoCCE). To provide optimal communications in a challenged environment or when operating with unintentional interference sources, BRSE with RoCCE will require significant effective increase in dynamic range across the full HF band of operation.

Communication signal interference sources can be intentional (e.g., "jamming") with wide variety of forms or unintentional. The latter includes Electromagnetic interference (EMI), Co-channel interference (CCI), Adjacent-channel interference (ACI), Inter-symbol interference (ISI), Inter-carrier interference (ICI), and Common-mode interference (CMI). Communications systems have various methods to deal with interferences such as adaptive equalization, Automatic Gain Control (AGC), analog filters, and advanced digital signal processing techniques. The communications systems, however, are limited in its ability to maintain the full dynamic range when the effects of interference cannot be fully addressed. The loss in dynamic range limits the effective data that can be transmitted in a communications channel.

Recent advancement in interference suppression and excision have resulted in commercially available stand-alone "appliances" such as iDirect's Communication Signal Interference Removal (CSIRTM) and the "Auto-tune Filter (AtF)" from Metamagnetics. While each of these systems work well on certain types of interference(s), there is not a single system that can properly categorize the interference(s) and orchestrate the activation of these interference suppression and excision to yield increased dynamic range and improved Signal to Noise Ratio (SNR) performance.

It is highly desirable for the WISDOM architecture to be realized in software and/or firmware hosted on the BFTN and its successors.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and

approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVWAR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Define the Wideband Interference Suppression for Dynamic-range OptiMization (WISDOM) architecture that will detect and categorize the interference type(s) and produce a strategy to mitigate the interferences thereof. The architecture should assume that either an analog “tap” or a digital copy (e.g., VITA 49.2 format) of the raw signal received by the radio will be made available to the WISDOM system.

During the Phase I Option period, if exercised, develop the SBIR Phase II Project Plan to include a detailed schedule (in Gantt format), spend plan, performance objectives, and transition plan for BFTN and any other PMW/A 170 identified Program of Record (PoR) to include BRSE, when the program is established.

PHASE II: Develop the prototype WISDOM for demonstration and validation in BRSE. Conduct Preliminary Design Review (PDR) for the WISDOM prototype and commence development of an Engineering Development Model (EDM) system. Conduct Critical Design Review (CDR) prior to building the EDM.

Develop lifecycle support strategies and concepts for the WISDOM.

Develop SBIR Phase III Project Plan to include a detailed schedule (in Gantt format) and spend plan, performance requirements, and revised transition plan for BRSE and any other PMW/A 170 identified Program of Record (PoR) to include Digital Modular Radio (DMR) and, objectively, with a candidate radio system from PMA/W 101. The name of PMA/W 101 radio system will be provided during Phase II execution period; for proposal purpose, use BRSE as an interim substitute with operation in L band (900 MHz to 2100 MHz).

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Refine and fully develop the Phase II EMD to produce a Production Representative Article (PRA) of the WISDOM and integrate into BRSE. Evaluate the potential to perform integration with other PMW/A 170 identified Program of Record (PoR) to include Digital Modular Radio (DMR) and PMA/W 101 radio system.

Perform Formal Qualification Tests (FQT) (e.g., field testing, operational assessments) of the PRA WISDOM, preferably embedded in BRSE.

Provide lifecycle support strategies and concepts for WISDOM potential as embedded in BRSE by developing an amended Life-Cycle Sustainment Plan (LCSP) for BRSE.

Investigate the dual use of the developed technologies for commercial applications such as in telecommunications. With 5G, new waveforms must be capable of supporting a greater density of users (e.g., up to a million devices per square kilometer) and higher data throughput (speeds in the Gbps), and provide more efficient utilization of available spectrum. WISDOM can potentially provide the high dynamic range and interference suppression capabilities to meet these needs.

REFERENCES:

1. “Radio jamming.” Wikipedia, the Free Encyclopedia, July 24, 2020.”
https://en.wikipedia.org/wiki/Radio_jamming
2. “Interference (communication).” Wikipedia, the Free Encyclopedia, July 24, 2020.
<https://en.wikipedia.org/wiki/Interference> (communication)
3. “Communication Signal Interference Removal (CSIRTM)” iDirect GOVERNMENT, July 24, 2020.
<https://idirectgov.com/products/glowlinksignalmanagementandmonitoringproducts/removecsir>
4. “Auto-tune Filter (AtF).” Metamagnetics, July 24, 2020. <https://www.mtmgx.com/resources/auto-tune-filter-mm-02c-0320.pdf>
5. “Summary of the 2018 National Defense Strategy.” U.S. Department of Defense, July 24, 2020.
<https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>

KEYWORDS: RF; Radio Frequency; Interference Suppression; Interference Excision; Interference Excision System; IES; Battle Force Tactical Network; BFTN; Robust Communications for Challenging Environments; RoCCE; BFTN Resilient Command and Control; System Enhancement

N211-081

TITLE: Novel Flow Control Strategies for High-Speed Inlets and Isolators

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Air Platforms; Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Conceive, develop, and demonstrate innovative flow control methodologies that increase inlet system recovery and operability while decreasing inlet-isolator length and combustor-entrance flow distortion without requiring bleed.

DESCRIPTION: The performance of high-speed air-breathing weapons is highly dependent on the inlet performance and operability under a range of inflow Mach numbers, altitudes, and vehicle angles-of-attack and yaw angles. [Ref 1]

Fixed-geometry inlets are desirable due to their mechanical simplicity, but on-design operation is limited to a narrow range of conditions. Off-design modes of inlet operation occurring during acceleration and maneuvers generate highly complex and potentially unstable flowfields that can lead to unpredictable consequences such as inlet unstart. [Refs 2, 3] The unstarted inlet flowfield is characterized by a large separated region and supersonic flow spillage. In general, an unstarted inlet captures less airflow with lower efficiency and higher aerodynamic and thermal loads compared to a started inlet. [Ref 1]

This SBIR topic aims to develop flow control strategies to improve the inlet flow delivered to scramjet or ramjet combustors. Promising control strategies are not limited to, but may include, mechanical protuberances and fluid injection devices [Ref 4], and their optimal placement in an inlet/isolator system in conjunction with inlet and isolator duct shaping. Figures of merit for flow control strategies include improved flow uniformity at the inlet throat and exit of the isolator, improved inlet flow stability, increased inlet compression efficiency or compression ratio capability, and reduced inlet-isolator system length. Solutions that enable or enhance the performance and operability of a fixed-geometry inlet without bleed are especially attractive. While an unstart detection system is not the focus of this SBIR topic, there is benefit in developing control methodologies that provide the ability to rapidly add pressure margin to the inlet operation if insipient unstart of the inlet is detected.

Recent improvement in high-fidelity simulations [Refs 5, 6] and optimization methodologies [Ref 7] provide new avenues to design, analyze and optimize novel inlet-isolator control devices. The design of the control devices needs to be guided by numerical simulations and optimization methodologies that includes aerodynamics and thermo-structural considerations. Validation of the analytical and numerical toolsets against wind-tunnel experiments under relevant high-supersonic and hypersonic flight conditions is also needed.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and

approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and ONR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Develop a conceptual design for innovative flow control strategies to improve the performance and operability of the inlet-isolator system. The proposed flow control solution(s) shall be developed using suitable computational methodologies to estimate improvements in the relevant performance metrics such as flow uniformity, inlet-isolator length and compression efficiency. The suitability of the computational methodologies for the design and analysis of inlet-isolator control solutions must be demonstrated. Therefore, validation against relevant experimental data for hypersonic inlets and isolators will be a key consideration towards successful phase transition. The analysis must show that the proposed flow control solution(s) enable a significant improvement in the performance metrics outlined above in the Description as the inlet-isolator design is driven toward more compact configurations. Develop a Phase II plan.

PHASE II: Refine, optimize and validate the proposed flow control strategies. Mature the computational design and optimization methods. Perform required validation against wind-tunnel experiments under relevant high-supersonic and hypersonic flight conditions to gain confidence in the design methodology and to accurately quantify the improvements to the performance metrics. Perform successful execution of ground tests validating the flow control solution(s), refinement of numerical simulation tools incorporating experimental data, and a detailed plan towards integrating the proposed concept(s) in a Navy relevant flight vehicle in Phase III all criteria for phase transition.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Seek further maturation of the flow control solution(s), including its manufacturability. Demonstrate the flow control solution(s) on a relevant Navy weapons geometry once a sufficient TRL is achieved.

In the near term, this technology is geared toward military applications, but in the longer term, it could be used to enable commercial hypersonic flight. Commercial hypersonic platforms will likely rely on a turbine-based combined cycle (TBCC) propulsion system that requires inlet operation over a wide range of Mach numbers and low flow distortion for turbine operation.

Commercialization can include both flow control devices, and the toolset for design, analysis and optimization (devices geometry, placement and integration) of these devices.

REFERENCES:

1. Van Wie, D.M. "Scramjet Inlets." Scramjet Propulsion, AIAA, 2000, pp. 447-511. <https://arc.aiaa.org/doi/abs/10.2514/5.9781600866609.0447.0511>
2. Zvegintsev, V.I. "Gas-dynamic problems in off-design operation of supersonic inlets (review)." Thermophysics and Aeromechanics, vol. 24, no. 6, 2017, pp. 807-834. <https://link.springer.com/article/10.1134/S0869864317060014>
3. Chang, J.; Li, N; Yu, K.; Bao, W. and Yu, D. "Recent research progress on unstart mechanism, detection and control of hypersonic inlet." Progress in Aerospace Sciences, vol. 89, February 2017, pp. 1-22, 2017. <https://www.sciencedirect.com/science/article/abs/pii/S037604211630080X>

4. Valdivia, A.; Yuceil, K.B.; Wagner, J.L.; Clemens, N.T. and Dolling, D.S. "Control of Supersonic Inlet-Isolator Unstart Using Active and Passive Vortex Generators." AIAA Journal, vol. 52, no. 6, 2014. <https://arc.aiaa.org/doi/10.2514/1.J052214>
5. Bisek, N.J. "High-Fidelity Simulations of the HIFiRE-6 Flow Path." AIAA 2017-1480, 2016. <https://arc.aiaa.org/doi/abs/10.2514/6.2016-4276>
6. Lyubimova, D.A. and Chestnykha, O.A. "Flow in a High-Velocity Mixed Compression Inlet Studied by the RANS/ILES Method in Different Operation Modes." High Temperature, vol. 56, no. 5, 2018, pp. 702–710. <https://link.springer.com/article/10.1134/S0018151X18040132>
7. Kline, H.L. and Alonso, J.J. "Adjoint of Generalized Outflow-Based Functionals Applied to Hypersonic Inlet Design." AIAA Journal, vol. 55, no. 11, 2017. <https://arc.aiaa.org/doi/full/10.2514/1.J055863>

KEYWORDS: Flow control; high-speed; hypersonics; inlet; isolator; air-breathing; weapons

N211-082 TITLE: Accelerated Learning Model for Increased Strategic and Tactical Decision Making Using Multi-player Games

RT&L FOCUS AREA(S): Machine Learning/AI; General Warfighting Requirements

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Increasing complexity in many military roles may require increased cognitive agility in areas of situation assessment, strategic and tactical decision making and better skill interpreting information in order to evaluate the need for a change in plans. Significant research has shown that it takes years and many repetitions for an individual to gain the skills. This cultivated knowledge and decision-making capability is necessary to develop expertise in any of these areas. However, recent research suggests that skill acquisition can be accelerated. This proposal explores a learning model that may help military personnel develop the necessary capabilities much faster using virtual environments with granular feedback, which have been shown to accelerate learning.

DESCRIPTION: Significant research has shown that it takes years and many repetitions for an individual to gain the skills, knowledge, and decision-making capability necessary to become an expert in a field. Recent research suggests that this requirement can be accelerated. **Two** questions come to mind: 1. Given recent research on accelerated learning in specific domains [Ref 1], can expertise that traditionally required years to master take only days or weeks to achieve? 2. What are the implications for expertise in broad cognitive capabilities such as situation assessment, strategic thinking, and tactical or general cognitive agility? Understanding these questions is crucial and time sensitive since the world is maneuvering and innovating faster across key domains including technology, military, politics, business, and education.

The interest in accelerating the mastery of expertise has a long history [Refs 2, 3]. Schneider et al [Ref 4] posited that those considered experts are qualitatively different from novices and journeymen. The process of becoming an expert takes years. He claimed that training the traditional route would not enable novices and journeymen to achieve the highest levels of expertise. Rather than traditional methods of training, the instructional designer and trainer must plumb the depths of learning strategies of those who would be experts. However, recently there has not been interest in this area of research, as evident by the dates of the publications referenced. It is time to revisit this area with the research described in this SBIR topic. This research could support an updated model of expertise acquisition that would advance training environments.

PHASE I: Develop a concept for an advanced training environment in the form of a multi-player game. Identify learning design features that encourage rapid learning. Base the architecture of the game on a model of accelerated learning as applied to military personnel. Ensure that the intent of the game should be to train combat personnel to operate successfully in urban battle settings. Produce and submit a final report that is a design document that describes the multi-player game features and includes a Phase II plan that describes a technical approach to achieve the desired result/product; and includes key component technological milestones such as the proposed experimental design to validate the resulting accelerated learning algorithms within the context of relevant operational tasks and environments.

PHASE II: Apply the instructional design accelerated learning principles in Phase I to a proof-of-concept technical feasibility demonstration. Empirically test the learning model by applying it via a virtual learning environment to a complex military problem. The virtual learning environment should be game based and multiplayer. Junior officers and senior non-commissioned officers (NCOs) will be the target users for the proof of concept. Validate training scenarios. Develop a data collection plan that includes the number and type of subjects; control condition, assessment instruments, and analysis plan.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the resulting technology for use in operational environments. Private Sector Commercial Potential: This SBIR topic would provide much needed theory, principles and technology to help the Navy/USMC introduce accelerated learning principles to both instructional designers, instructional personnel, and military personnel. The principles and technology would have broad applicability to learning endeavors within the military and to civilian training interests, particularly commercial game developers.

REFERENCES:

1. Hoffman, R.R., Ward, P., Feltovich, P.J., DiBello, L., Fiore, S.M. and Andrews, D. "Accelerating Learning and Expertise: Concepts and Applications." Human Factors and Ergonomics Society Annual Meeting Proceedings 54(4), September 2010, pp. 399-402.
https://www.researchgate.net/publication/288495066_Accelerated_Learning_Prospects_Issues_and_Applications
2. Chi, M., Feltovich, P., and Glaser, R. "Categorization and representation of physics problems by experts and novices." Cognitive Science, 5(2), 1981, pp. 121-152.
<https://apps.dtic.mil/dtic/tr/fulltext/u2/a100301.pdf>
3. Chi, M. T. H., Glaser, R. and Rees, E. "Expertise in problem solving." R. J. Sternberg (Ed.) Advances in the psychology of human intelligence, Vol. 1, pp. 7-75.
<https://www.public.asu.edu/~mtchi/papers/ChiGlaserRees.pdf>
4. Schneider, V. I., Healy, A. F. and Bourne, L. E., Jr. "What is learned under difficult conditions is hard to forget: Contextual interference effects in foreign vocabulary acquisition, retention, and transfer." Journal of Memory and Language, 46, 2002, pp. 419-440.
https://www.academia.edu/19510017/What_Is_Learned_under_Difficult_Conditions_Is_Hard_to_Forget_Contextual_Interference_Effects_in_Foreign_Vocabulary_Acquisition_Retention_and_Transfer

KEYWORDS: Multiplayer Game; Training; Accelerated Learning Algorithms; Advanced Training Environments; Rapid Learning; Operational Tasks and Environments; and Urban Warfare

N211-083 TITLE: Automated Formal Verification of Software Defined Network Implementations

RT&L FOCUS AREA(S): Cybersecurity; Autonomy

TECHNOLOGY AREA(S): Battlespace Environments; Electronics; Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an automated tool suite to formally verify correctness of software defined networks (SDNs), from programming to network implementations, subject to Fifth Generation (5G) New Radio (NR) standards and protocols.

DESCRIPTION: Cybersecurity vulnerabilities commonly arise from flawed implementations. To minimize attack surfaces while harnessing the full power of Fifth Generation (5G) New Radio networks, innovative solutions that identify flaws and formally verify correctness of underlying SDNs are required. Furthermore, automation will relieve the burden on operators who often validate code empirically, and will facilitate rapid, secure reconfigurability of SDNs. This SBIR topic addresses the challenge of automating formal verification of code and network correctness, which has thus far limited such technology to Industrial Control System applications. The innovative solution sought is an automated tool suite that identifies SDN programming flaws or malicious content and employs formal techniques to prove correctness of network implementations.

PHASE I: Define and develop a concept framework for an automated tool suite that will formally verify correctness of complete SDN implementations, ensuring compliance with any applicable NIST and ISO/IEC 27000 standards. Evaluate the type and source of vulnerabilities that could potentially be exploited as a result of faulty SDN implementations from programming flaws and malicious code to the actual network instantiation, considering both accidental and malicious events. Provide measures of effectiveness for such tools, as well as attainable performance characteristics. The framework will need to be flexible and extensible across a set of hardware systems, with a proposed design for the hardware and software architectures that will be incorporated into 5G-enabled cyber physical systems for assured cyber resilience. The design should include a summary of any computing and power requirements for administering these cybersecurity tools. The feasibility of the concept will be established through modeling and simulation. Include, in a Phase II plan, the initial design specifications and capabilities description to build prototype tools in Phase II.

PHASE II: Fully develop, verify, and validate prototype automated tools that formally verify correctness of complete SDN implementations subject to applicable standards and protocols (e.g., 5G NR, NIST, and ISO/IEC 27000) for evaluation. Design the prototype tool suite to provide formal verification of code and network functionality prior to instantiation. Demonstrate the design performance through modeling and physical testing over a range of scenarios devised to test network vulnerabilities with and without the cyber resilient layer in place. Use evaluation criteria and results to refine the prototype tool suite into an initial design that can be deployed in relevant and/or operational environment settings, and that support mission requirements in the cyber domain, which ultimately ensures the confidentiality, integrity, and

availability of data. Develop a Phase III plan to transition the technology to a system that can be acquired by the Navy.

PHASE III DUAL USE APPLICATIONS: Support Navy system integration of the cybersecurity framework, hardware and software, employing any lessons learned from the Phase II evaluation. Incorporate the automated tool suite into security assessments that support both any existing and future SDN implementations. This integration will also include validation testing and demonstration on a representative 5G-networked system. The automated tool suite developed in this SBIR effort would support formal verification of correct SDN applications in 5G networks used by industry, infrastructure, energy, health care, and other applications where cyber attacks due to flawed implementation may be expected to interfere with the integrity or availability of data and analysis from 5G-enabled cyber physical systems.

REFERENCES:

1. Ball, T., Bjørner, N., Gember, A., Itzhaky, S. Karbyshev, A. et al. “VeriCon: Towards Verifying Controller Programs in Software-Defined Networks.”, Proc. 35th ACM SIGPLAN Intl. Conf. Programming Language Design (PLDI'14), 2014, pp.282-293.
<http://www.cs.technion.ac.il/~shachari/dl/pldi2014.pdf>
2. Canini, M., Venzano, D., Pereskini, P., Kostic, D. and Jennifer, R. “A Nice Way to Test OpenFlow Applications.” Proceedings of the 9th USENIX conference on Networked Systems Design and Implementation (NSDI'12), 2012.
<https://www2.cs.duke.edu/courses/fall14/compsci590.4/Papers/NICE12.pdf>
3. Darvas, D., Majzik, I., Blanco Viñuela, E. “Formal verification of safety PLC based control software.” E. Ábrahám, M. Huisman (Eds.). Integrated Formal Methods, vol. 9681 (Lecture Notes in Computer Science), Springer, 2016. https://dl.acm.org/doi/10.1007/978-3-319-33693-0_32
4. Kim, H., Reich, J., Gupta, A., Shahbaz, M., and Feamster, N. et al. “Kinetic: Verifiable Dynamic Network Control.” Proceedings of the 12th USENIX Conference on Networked Systems Design and Implementation (NSDI'15), 2015.
<https://www.usenix.org/system/files/conference/nsdi15/nsdi15-paper-kim.pdf>
5. Schnepf, N., Badonnel, R., Lahmadi, A. and Merz, S. “Automated Verification of Security Chains in Software-Defined Networks with Synaptic.” NetSoft 2017 - IEEE Conference on Network Softwarization, Bologna, Italy, July 2017. <https://ieeexplore.ieee.org/document/8004195>

KEYWORDS: Software Defined Network; SDN; Automated Tools; Formal Methods; Formal Verification; 5G

N211-084 TITLE: Low Cost, Single Use Precision Aiming Device for Explosive Ordnance Disposal Disrupters and Tools

RT&L FOCUS AREA(S): Autonomy; General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments; Ground / Sea Vehicles

OBJECTIVE: Develop and demonstrate a low cost, single shot, precision aiming device designed to fit onto multiple Explosive Ordnance Disposal Disrupters.

DESCRIPTION: Explosive Ordnance Disposal (EOD) disrupters and tools are used to remotely open or render safe a suspect item or improvised explosive device (IED). Current precision aiming systems utilize reusable lasers that are expensive and under certain recoil forces/conditions exhibit limited survivability. The EOD community has identified the need for a low cost, lightweight, precise aiming capability for one-time use (single shot) on a variety of disrupters and tools. The aiming capability should aim and hit a variety targets with different surfaces at a standoff distance threshold of 25 feet and objective of 50 feet. It should have an aim-spot accuracy of approximately 0.955 inches (the diameter of a U.S. quarter). The capability should be able to wrap around multiple disrupter/tool barrels with a threshold requirement of 1"-2" diameters and an objective requirement of 1"-6" diameters. Separate configurations to achieve the range of 1"-6" diameters is acceptable. Battery operation of the device is acceptable. A concept of employment that provides minimal setup time with no tools is preferred along with the smallest, lightest weight configuration. Operators should be able to see the aim-spot in daylight with their eyes and remotely through a camera interface. At night, the capability should be infrared (IR) or night vision compatible. Examples of evaluations and descriptions of some DoD, local and state bomb squad disrupters and laser aiming devices are provided in References (1) and (2).

The innovation of this research is in the development of a precision aiming device that is one use, lightweight, low cost and capable of easy operator set up on multiple diameter disrupters and tools. Novel laser or non-laser solutions are acceptable.

PHASE I: Define, develop and possibly validate the initial design concept for a low cost, single shot, precision aiming device. If requested, the Government can provide an inert 155mm round fuze as an exemplar validation target. Provide a final report of the initial work and results for the single shot precision aiming device, the concept of employment for the various disrupter sizes, a device cost forecast and Phase II implementation plan.

PHASE II: Produce prototype hardware. Develop, demonstrate and validate the design. The Government can provide test opportunities on actual systems if the validation work is mature enough to enable a viable test.

PHASE III DUAL USE APPLICATIONS: Transition the device to the Joint Service Explosive Ordnance program. Manufacture a sufficient number of devices to support a statistically relevant field test validation and verification using a variety of disrupters. Additionally, the device could transition to use by state and local bomb squads.

REFERENCES:

1. U.S. Department of Homeland Security. "Explosive Ordnance Disposal Disrupters." System Assessment and Validation for Emergency Responders (SAVER), June 2012.
https://www.dhs.gov/sites/default/files/publications/EODDisrupters-SUM_0612-508.pdf

2. U.S. Department of Homeland Security. "Laser Aiming Devices for EOD Disrupters." System Assessment and Validation for Emergency Responders (SAVER), May 2013.
https://www.dhs.gov/sites/default/files/publications/LaserAimingDevices-SUM_0513-508_0.pdf

KEYWORDS: EOD; disrupter; precision; aiming; device; single-use; low-cost

N211-085

TITLE: Developing Alloy Compositions Conducive to Additive Manufacturing

RT&L FOCUS AREA(S): Machine Learning/AI; General Warfighting Requirements

TECHNOLOGY AREA(S): Air Platforms; Ground / Sea Vehicles; Materials / Processes

OBJECTIVE: Develop alloy compositions that enable additive manufacturing (AM) processes to produce properties that are not currently achievable such as materials with a preferred crystallographic orientation, dispersion-forming alloys that can either form the dispersion during AM or after AM through heat treatment. Alloy compositions should reduce defects in components, thus promoting them to be more resistant to fatigue, with potential increases in strength.

DESCRIPTION: Additive work is being done on current cast and wrought alloy compositions trying to achieve original alloy properties. Achieving such properties is difficult because of the varying solidification conditions inherent in different AM processes and part designs. AM alloys have a complex thermal history involving directional heat build-up and repeated melting and rapid solidification. AM usually results in a finer microstructure than conventional processing which gives the AM material better fatigue properties, but debited creep properties. Modifying alloy compositions to take advantage of AM solidification variables could take advantage of AM to improve alloy properties. The interaction of alloying elements is recognized in promoting desirable microstructural phases and solid-solution effects for development of properties. The use of Integrated Computational Materials Engineering (ICME) should relate AM processability with alloy chemistry in order to develop models that are able to predict alloy chemistry that minimizes defects while maintaining base alloy properties. This could be done by linking materials data sets, modeling, and AM variables in a machine learning framework to achieve properties. The condition under which solidification takes place determines the structural features that affect the physical and mechanical properties of an alloy. Melting and solidification are generally well-understood during casting processes, but melting and solidification profiles, effect of contamination, and alloy chemistry control during cyclic AM processing, particularly for complex and thicker components, are also not well characterized.

PHASE I: Explore the literature to determine the relationship of wrought alloys chemical compositions and the chemistries of its cast alloy corollaries, understand the underlining reasons for the different chemistries to enable an alloy to be similar by each process. The company should select an AM process which has a good understanding of the heat transfer, solidification variables, and factors which cause defects. Focus on IN 718 or Alloy 230 with the goal of producing properties equivalent to or greater than achieved by the wrought alloy. Develop conceptual models/algorithms that link alloy chemistry to AM processes and resulting alloy microstructure and subsequent mechanical properties. Company needs to show that alloy chemistry models can consistently predict the alloy physical and mechanical properties for the AM process selected. Consider powder chemistry and size distribution. Analysis of the defects is suggested to be done by non-destructive processes such as optical tomography, in-situ thermographic analysis, ultrasonic monitoring or x-ray tomography. ICME should link to AM process parameters with defect frequency and distribution in the component design, employ and prove feasibility of an approach for a metal AM method. Develop a Phase II plan.

PHASE II: Based upon Phase I effort, apply ICME tools to optimize metal AM processing and to predict design and processing parameter limits for a more complex component. Consider computational models and relevant databases. Since most AM metal processes are layer--by-layer, work need to model the change in heat transfer as the layers are added to previous layers in an effort to minimize microstructural changes within the component. Determine relative sensitivity of different chemistry variables within a property model; and determine which variable is "most important" in controlling property value. Work to optimize the alloy chemistry/processing/property model by selecting another nickel-base alloy or an iron-

based alloy to explore an alloy family. Collaborate with a powder manufacturer for powder size distributions for AM systems. Ensure that the program provides a means for capturing, sharing, and transforming materials data into a structured format that is amenable to transformation to other formats for use by ICME and other computational programs, modeling, and simulation methods. Demonstrate the functionality of this framework.

PHASE III DUAL USE APPLICATIONS: The AM process and alloy chemistries that are suited specifically for AM processes offers the opportunity of conformal, and unique design not possible with more conventional fabrication processes. Proven AM process optimization leading to a minimization of process - and materials - derived defects would improve acceptance of AM for producing component for the Navy and for private industry. The use of AM could lead to more innovative 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. The use of AM could lead to more innovative designs capable meet ever-increasing demands on components for the Navy as 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 more quickly. Engage with the Government and/or public, commercial, company, or professional technical societies that retain materials databases. Interface with a software company that promotes and delivers materials computational programs to explore and develop an integration pathway for the database discriminating program with their software. The outcome of this technology development program will be a commercial suite of informatics-derived tools that can be able to reliably analyze and discriminate various sources of materials databases to optimize the capability for materials prediction. Transition the material production methodology to a suitable industrial material producer. The ICME code needs to be transitioned to the commercial entity for potential incorporation of a more comprehensive ICME code. Commercialize the alloys for use in DoD and commercial markets.

REFERENCES:

1. Mitchell, A. "Melting, Casting, and Forging Problems in Titanium Alloys." *Materials Science and Engineering A*, v.243(1-2), 1998, pp.257-262.
<https://www.sciencedirect.com/science/article/abs/pii/S0921509397008101>
2. Jablonki, P.D., Hawk, J.A., Cowen, C.J. Maziasz, P.J. "Processing of Advanced Cast Alloys for A-USC Steam Turbine Applications." *JOM*, v 64, 2012, pp. 271-279.
<https://ui.adsabs.harvard.edu/abs/2012JOM...64b.271J/abstract>
3. Dobrzanski, L.A., Tanski, T., Cizek, L. and Brytan, Z. "Structure and Properties of Magnesium Cast Alloys." *J. of Materials Processing Technology*, v.192-193, 1 October 2007, pp.567-574.
<https://www.sciencedirect.com/science/article/abs/pii/S0924013607004232>
4. Harris, K., Erickson, G.L. and Schwer, R.E. "MAR M 247 DERIVATIONS - CM 247 LC DS ALLOY CMSX SINGLE CRYSTAL ALLOYS PROPERTIES & PERFORMANCE." 5th International Symposium on Superalloys, 1984, pp.221-230.
https://www.researchgate.net/publication/265945421_MAR_M_247_Derivations_-_CM_247_LC_DS_Alloy_and_CMSX_Single_Crystal_Alloys_Properties_Performance
5. Carter, L.N., Attallah, M.M. and Reed, R.C. "Laser Powder Bed Fabrication of Nickel-Base Superalloys: Influence of Parameters; Characterisation, Quantification and Mitigation of Cracking." *Superalloys 2012*, The Minerals, Metals, and Materials Society, 2012, pp.577-586.
https://www.tms.org/superalloys/10.7449/2012/Superalloys_2012_577_586.pdf
6. Sames, W.J., List, F.A., Pannala, S., Dehoff, R. and Babu, S.S. "The metallurgy and processing science of metal additive manufacturing." *International Materials Reviews*, v. 61(5), 2016, pp.315-360. <https://www.osti.gov/pages/servlets/purl/1267051>

KEYWORDS: Additive manufacturing; alloys; Integrated Computational Materials Engineering; ICME; solidification; processing; alloy chemistry; heat transfer; defects

N211-086

TITLE: N-Polar Gallium Nitride High Electron Mobility Transistor in Low-Cost Process Technology for mm-wave Transceiver Applications

RT&L FOCUS AREA(S): 5G; Microelectronics

TECHNOLOGY AREA(S): Electronics; Materials / Processes; Sensors

OBJECTIVE: Demonstrate robust N-polar Gallium Nitride (GaN) E-band low noise amplifiers (LNAs) with <3.5 dB noise figure at 83 GHz, and device NF_{min} < 1 dB at 30 GHz. The device and LNAs must use a native growth N-polar epitaxy process on a low-cost substrate that can be scaled to diameters of 150 mm and above.

DESCRIPTION: N-polar GaN has demonstrated breakthrough high-power density performance in the W-band, and matched or exceeded power performance of traditional Ga-polar GaN at lower frequencies including X and Ka-band. GaN transistors and monolithic microwave integrated circuits (MMICs) today are expensive, with a significant portion of the cost coming from the Silicon Carbide (SiC) substrates and their smaller diameters (200 mm substrates will lower MMIC cost by 6X for low cost substrates). Alternate substrates will be lower thermal conductivity and/or increased microwave loss, the impact of which should be considered. A single epitaxial structure will lead to a 50% reduction in integration cost of an LNA, Power Amplifier (PA) and transmit / receive (TR) switch. Tradeoffs in performance of individual circuits is anticipated in order to meet the topic objectives in a single device epilayer structure. Examples for the current state of the art for Ga-polar GaN HEMT on SiC follow; HRL's T4A process provides excellent NF_{min} below 1 dB at 30 GHz and approximately 0.5 W/mm power density. Ga-polar GaN-on-SiC HEMT's data at 94 GHz at 2 W/mm and 22% power-added-efficiency (PAE) has been reported. Nitrogen polar (N-polar) GaN HEMTs, at 94 GHz, have demonstrated ~9 W/mm at 28% PAE on SiC and 4 W/mm, 30% PAE on Sapphire. N-polar GaN LNA's have not been reported. Availability of N-polar GaN device materials in substrate diameters from 100-200 mm is being established through DoD investment in technology transition and manufacturing.

PHASE I: Design and fabricate a low noise N-polar GaN HEMT device with noise figure (NF) min <3 dB at 83 GHz and <1 dB at 30 GHz, with epitaxy grown on a low-cost substrate and with an epitaxial design capable of supporting both power amplifier devices with >4 W/mm and $>25\%$ PAE and transmit/receive (T/R) switches. Characterize noise and S-parameters and extract noise and linear models. Develop a Phase II plan.

PHASE II: Refine the design of and fabricate a prototype E-band 81-86 GHz LNA demonstrating <3.5 dB NF_{min} and >15 dB gain. Characterize the noise and small-signal performance. On the same wafer, fabricate split path, double throw (SPDT) T/R switches and characterize their performance at small and large signal level under continuous wave (CW) conditions. Based on the measured performance, survey and identify E-band transceiver applications for the Phase II results.

PHASE III DUAL USE APPLICATIONS: There are many emerging transceiver applications for both DoD and commercial systems for E-band. The U.S. Federal Communications Commission has established that portions of E-band are available in the U.S. for high density, high data rate wireless services that will enable point-to-point communications, SATCOM, and 5G services. The International Telecommunication Union permits several bands for radio and satellite operations. For example, SpaceX has applied to use portions of E-band in their Starlink Gen2 satellite constellation. E-band will enable new high-resolution imaging and surveillance sensors for DoD systems and commercial applications such as autonomous vehicles. In Phase III, transition and demonstrate the N-polar device fabrication to a full wafer fabrication at wafer diameters > 150 mm. Refine the designs developed in the Phase II. Based on the phase II application survey for an E-band transceiver application, develop the TR module

specifications to satisfy this application. Design and fabricate a prototype integrated TR module and package into a waveguide housing with all bias and control signals integrated. Characterize under relevant operating conditions. Based on the results, further refine the designs.

REFERENCES:

1. Wienecke, S. et al. "N-Polar Deep Recess MISHEMTs with Record 2.9 W/mm at 94 GHz." IEEE Electron Device Lett., vol. 37, no. 6, June 2016. doi: 10.1109/LED.2016.2556717
2. Romanczyk, B. et al. "mm-Wave N-polar GaN MISHEMT with a self-aligned recessed gate exhibiting record 4.2 W/mm at 94 GHz on Sapphire." 2016 74th Annual Device Research Conference (DRC), Jun. 2016, vol. 2016, pp. 1–2. doi: 10.1109/DRC.2016.7548464
3. Romanczyk, B. et al. "Demonstration of Constant 8 W/mm Power Density at 10, 30, and 94 GHz in State-of-the-Art Millimeter-Wave N-Polar GaN MISHEMTs." IEEE Trans. Electron Devices, vol. 65, no. 1, 2017, pp. 45-50. doi: 10.1109/TED.2017.2770087
4. Romanczyk, B., Zheng, X., Guidry, M., Li, H., Hatui, N., Wurm, C., Krishna, A., Ahmadi, E., Keller, S. and Mishra, U.K. "W-Band Power Performance of SiN-Passivated N-Polar GaN Deep Recess HEMTs." IEEE Electron Device Lett., vol. 41, no. 3, 2020, pp. 349-352. doi: 10.1109/LED.2020.2967034
5. Kurdoghlian, A. et al. "First demonstration of broadband W-band and D-band GaN MMICs for next generation communication systems." 2017 IEEE MTT-S International Microwave Symposium (IMS), June 2017, pp. 1126-1128. doi: 10.1109/MWSYM.2017.8058796
6. Lardizabal, S., Hwang, K.C., Kotce, J., Brown, A. and Fung, A. "Wideband W-Band GAN LNA MMIC with State-of-the-Art Noise Figure." 2016 IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS), Oct. 2016, vol. 2016, pp. 1-4. doi: 10.1109/CSICS.2016.7751079
7. "Transphorm Announces \$18.5 Million Contract From Office of Naval Research to Establish Domestic Source of Gallium Nitride," Businesswire, July 30, 2019.
[https://www.businesswire.com/news/home/20190730005364/en/Bloomberg-
https://www.bloomberg.com/press-releases/2019-07-30/transphorm-announces-18-5-million-contract-from-office-of-naval-research-to-establish-domestic-source-of-gallium-nitride](https://www.businesswire.com/news/home/20190730005364/en/Bloomberg-https://www.bloomberg.com/press-releases/2019-07-30/transphorm-announces-18-5-million-contract-from-office-of-naval-research-to-establish-domestic-source-of-gallium-nitride)

KEYWORDS: GaN; Gallium Nitride; low noise amplifier; transceiver; High Electron Mobility Transistor; HEMT; Nitrogen Polar; Noise figure

N211-087 TITLE: Solid State High Voltage Power Module Development and Packaging for High Power Microwave Drivers

RT&L FOCUS AREA(S): Directed energy

TECHNOLOGY AREA(S): Electronics; Ground / Sea Vehicles; Weapons

OBJECTIVE: Develop and demonstrate compact power electronics modules capable of supporting power combining of solid state High Power Microwave (HPM) sources. Develop bond wireless technology to enable ultra-high voltage silicon carbide metal-oxide semiconductor field-effect transistor (SiC MOSFET), insulated-gate bipolar transistor (IGBT), Thyristor, and diode modules capable of higher pulse repetition rate operation for burst mode operation. Develop specialized test beds that have the ability to characterize the maximum di/dt and dv/dt limitations of SiC devices while determining the safe operating area (SOA) of the modules. Advance and verify switch characteristics such as fast rise time and low impedance to be able to drive specific HPM sources. Develop a compact, less than 1 ft³, packaged switch module capable of delivering 50-100 kV outputs that also has the ability to be combined to scale driver power. Demonstrate low jitter module operations to facilitate phased element design. This phased multi module system design will show the ability for scalable power and subsequent beam steering operations.

DESCRIPTION: Commercial grade SiC power electronic devices are available in the market; however, high voltage (HV) SiC devices have not been developed, tested, or packaged specifically for HPM applications. Research grade SiC MOSFET and IGBT dies have been packaged individually, but the maximum di/dt and narrow pulse capability have not been determined. In addition, HV IGBTs have not been packaged in modules. Ultra-high voltage SiC MOSFET, IGBT, Thyristor, and diode modules can be developed for narrow pulse fast rise time applications, while requiring unique drivers to optimize performance. The power density, long term reliability, efficiency, and control of directed energy systems can be improved through the utilization of novel SiC device modules. The fabrication of SiC has rapidly advanced in recent years with defect density and average carrier lifetime vastly improved, enabling stable and reliable operation. However, the device packaging has not been optimized for pulsed power switching that has very short times while being very high in voltage. The bond wires are a known failure point during high current switching that will need to be addressed.

Simulations show that SiC MOSFETs can be capable of up to 15 kV while SiC IGBTs are suitable from 15 kV to 35 kV, while higher voltages from 35 kV to 50 kV SiC gate turn off (GTO) Thyristors are the optimal choice [Ref 1]. Cree-Wolfspeed has developed a 15 kV SiC MOSFET and a 24 kV SiC IGBT as of 2016, though they are not in their standard product inventory [Refs 2, 3]. The rise-time of the MOSFET was 102 ns for an 8 kV, 28 A pulse while the IGBT had a switching speed of 46 kV/ μ s. Photoconductive semiconductor switches (PCSS) SiC have been developed to show switching voltages of 50 kV in experimental setups for a radial topology [Ref 4]. Behlke has developed HV solid state switching modules capable of switching 200 kV with a 1.6 kA current and a rise-time of 300 ns (HTS 2000-160). Behlke also has Thyristors capable of switching 150 kV with a 10 kA current and a rise-time of 35 μ s (HTS 1500-1000-SCR).

PHASE I: Conceptualize, design, and model key elements for an innovative, all solid-state power modulator capable of a threshold 50 kV and objective 100 kV at pulse repetition rates of tens of kHz or higher. The design should establish realizable technological solutions for a module capable of driving various HPM sources that have certain requirements in rise-time and impedances.

Requirements:

- The technical solution should have a minimum pulse repetition rate on the order of tens of kHz or higher.
- The conceptual design should focus on rise times of 10's of ns, <100 Ohm impedance, and jitter <1 ns to be able to drive specific HPM sources and accurately phase multiple modules.
- The proposed design should be an 80% complete solution and include all auxiliary systems associated with the control system for the power electronics, power buffer/energy magazines and thermal management.
- The design should include circuit modeling and analysis of the HV driver.
- The proposed brassboard system should be designed for both laboratory and limited open air testing with sufficient ruggedization to transport the hardware to test sites.

Perform additional modeling and simulation to determine predicted efficiency, prime power draw, and thermal management requirements. Provide an overview of the current state of the art for each of the key prototype elements along with manufacturer information, focusing on the solid state components required for this application, packaging and power density. Provide a cost analysis as well as material development to ascertain critical needs not yet fully developed or readily available given current technology. Develop a Phase II plan.

PHASE II: Refine the design of the proposed technology. Complete procurement, integration, assembly, and testing of a proof-of-concept brassboard prototype leveraging the Phase I effort. Requirements:

- The Phase II brassboard prototype will be capable of greater than 50 kV and a rep rate above 50 kHz, while being able to support low jitter (<1ns), fast rise-time (10's of ns) operations.
- The brassboard system should be capable of operating in a laboratory environment, such as an anechoic chamber or Gigahertz Transverse Electromagnetic (GTEM) test cell.
- This brassboard prototype must demonstrate a clear path forward to a full scale concept demonstrator based on the selected technology.

PHASE III DUAL USE APPLICATIONS: A successful project will also showcase the ability of the technology to match evolving needs of commercial markets such as medical pulse power and sterilization. Recent progress in medical pulse power research, utilizing high voltage short pulses to increase immunology efficacy has driven the need of a low jitter, fast rep-rate, low impedance, solid-state HV pulse generator. Several medical areas benefiting from these HV modulators include wound healing, cancer treatment, and gene transfer. Various commercial markets ranging from environmental, sanitization, and food processing has also shown increased efficacy when utilizing short, high voltage pulses. These applications can be realized by the development of a reliable, long lifetime, solid-state HV modulator.

Within DOD, we seek to apply the knowledge gained during Phase I and II to further build, refine and demonstrate a full scale prototype device capable of transmitting an arbitrary waveform at power levels exceeding 10 MW and a rep-rate on the order of tens of kHz or more. To allow this, it is suggested to ensure that the prototype represents a complete power modulator with controls, thermal management, energy magazine or prime power buffer; and is ruggedized for, at a minimum, testing in an outdoor environment and be environmentally enclosed; and includes at least 2 or more modules that shows active control over phasing and power combining.

REFERENCES:

1. Johannesson, D., Nawaz, M., Jacobs, K., Norrga, S. and Nee, H. "Potential of ultra-high voltage silicon carbide semiconductor devices." 2016 IEEE 4th Workshop on Wide Bandgap Power Devices and Applications (WiPDA), Fayetteville, AR, 2016, pp. 253-258. doi: 10.1109/WiPDA.2016.7799948.

2. Passmore, B. and O'Neal, C. "High-voltage SiC power modules for 10-25 kV applications." Power Electronics Europe, no. 1, 2016, pp. 22-24. https://www.wolfspeed.com/downloads/dl/file/id/854/product/0/high_voltage_sic_power_modules_for_10_25_kv_applications.pdf
3. Brunt, E.V. et al. "22 kV, 1 cm², 4H-SiC n-IGBTs with improved conductivity modulation." 2014 IEEE 26th International Symposium on Power Semiconductor Devices & IC's (ISPSD), Waikoloa, HI, 2014, pp. 358-361. doi: 10.1109/ISPSD.2014.6856050.
4. Hettler, C., Sullivan, W.W., Dickens, J. and Neuber, A. "Performance and optimization of a 50 kV silicon carbide photoconductive semiconductor switch for pulsed power applications." 2012 IEEE International Power Modulator and High Voltage Conference (IPMHVC), San Diego, CA, 2012, pp. 70-72. doi: 10.1109/IPMHVC.2012.6518682.
5. Benford, J., Swegle, J. and Schamiloglu, E. "High Power Microwaves." Copyright 2007. Published by CRC Press, December 10, 2019. <https://www.routledge.com/High-Power-Microwaves/Benford-Swegle-Schamiloglu/p/book/9780367871000>
6. Coleman, P. et al. "Characterization of a Synchronous Wave Nonlinear Transmission Line." Proc. Pulsed Power Conf., 2011, pp. 173-177. <https://www.osti.gov/servlets/purl/1107564>
7. Sullivan, J. "Wide Bandgap Extrinsic Photoconductive Switches." Lawrence Livermore Nation Laboratory Report, LLNL-TH-523591, Jan. 2012. <https://ui.adsabs.harvard.edu/abs/2013PhDT.....439S/abstract>

KEYWORDS: High Power Microwave (HPM); Solid state switch; High Voltage (HV) switch; power modulator; power electronics

N211-088

TITLE: Live, Virtual, and Constructive Cyber Battle Damage Assessment for Training

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Electronics; Human Systems; Information Systems

OBJECTIVE: Research, design, and develop intelligent cyber sensors that can accurately detect cyber range-based state information and distribute to traditional training architectures to enable integrated cyber-kinetic training opportunities.

DESCRIPTION: Cyber ranges, as the primary environment for conducting cyber training, must be able to collect key cyber state information, also known as cyber Battle Damage Assessment (BDA), and share this information with traditional simulation architectures and systems. This ability is foundational to creating an integrated cyber-kinetic training environment and requires the development of sensors that can accurately detect Live, Virtual, and Constructive (LVC) cyber effects of interest such as Denial, Disruption, Degradation, Destruction, and Manipulation (4DM).

PHASE I: Identify shipboard C4I System interfaces and data flow vulnerable to a Great Power Competitor's Signal Intelligence (SIGINT) and the interfaces of these systems to the Navy Continuous Training Environment (NCTE). Develop the design of a system/software scheme that would allow "live" signals to effect "virtual" simulations of identified shipboard C4I system. Submit the scheme for validation by Fleet Information Warfare (IW) Subject Matter Experts (SME), NCTE Interface Engineers, and Fleet Training SMEs from Tactical Training Group Pacific (TTGP) for a review at Naval Simulation Center Pacific (NSCPAC) San Diego CA. Provide all software designs, a description of software and hardware to be developed in Phases II and III, and a demonstration plan and scenario that will be executed at NSCPAC. Develop a Phase II plan.

PHASE II: Build and test a usable prototype of the software and hardware to be tested in the NSCPAC lab to demonstrate the ability to bring live signals into a virtual ship's identified C4I systems. Ensure that the deliverable will be a test ready article (hardware and software), which will be used in Phase III to test and demonstrate in a Fleet Synthetic Training (FST) Unit level event. Ensure that this prototype will use the Research, Development, Test, and Experimentation (RDTE) NCTE architecture and Joint Semi-Automated (JSAF) simulation for scenario and transport inside of NSCPAC. Tactical Training Group Pacific (TTGP) will act as the Distributed Training Center (DTC) and will provide IW SMEs to evaluate the prototype for ease of use, representations of the injected IW signal on the virtual C4I system, and the output of the BDA to the C4I system. All software developed as part of this research will be provided to ONR and other identified government users without restriction.

PHASE III DUAL USE APPLICATIONS: Make available to the Navy all technologies developed under this SBIR topic. These technologies will be installed at Tactical Training Group Pacific (TTGP) and onboard an assigned Destroyer at sea during a LVC Composite Training Unit Exercise (COMPTUEX) offshore on the West Coast Tactical Training Range (WCTTR). Use of these technologies will help inform the Navy Fleet Training Program on how to use Operational/Tactical circuits to transport simulation & mentor data while at sea.

Private Sector Commercial Potential: Expansion of this technology for ship to and from aircraft, ship to and from submarines, and aircraft to and from submarines could be development opportunity for defense contractors, small businesses, and academia.

This technology could be expanded to improve operational and tactical capabilities that could be a "Game Changer" for the Navy.

REFERENCES:

1. “Cyber Operational Architecture Training System (COATS): Prototype cyber-kinetic training architecture demonstrated at U.S. Forces Korea’s exercise Ulchi Freedom Guardian 2015.” https://www.iitsec.org/-/media/sites/iitsec/link-attachments/best-papers-and-tutorials-from-past-iitsec/15108_sim_paper.ashx?la=en
2. “Cyber-Kinetic Effects Interface (CKEI): U.S. Army’s prototype interface for integrating Carnegie Mellon University’s Simulation, Training, and Exercise Platform (STEP) web-based cyber training environment, One Semi-Automated Forces (OneSAF), and the Network Effects Emulation System (NE2S).” https://insights.sei.cmu.edu/sei_blog/2017/03/combined-arms-cyber-kinetic-operator-training.html
3. “Simulation Interoperability Standards Organization’s (SISO) Cyber M&S Study Group: Defining requirements and designing a cyber-data exchange model for cyber information sharing between cyber ranges, simulation systems, and operational systems.” <https://www.sisostds.org/StandardsActivities/StudyGroups.aspx>

KEYWORDS: Cyber; Training; Information Operations; Shipboard Applications; Kinetic Operations; Damage Assessment; Live, Virtual, and Constructive; LVC; Electronic Systems

N211-089

TITLE: Airborne LIDAR Ocean Temperature Measurement

RT&L FOCUS AREA(S): General Warfighting Requirements

TECHNOLOGY AREA(S): Battlespace Environments; Information Systems; Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and demonstrate an airborne capability to measure with fidelity the temperature of the ocean across the upper part of the water column, where it is most variable - and therefore produces the greatest effects upon acoustic propagation. Fidelity will necessarily vary as a function of platform altitude, platform velocity, and atmospheric properties. Validate an understanding of the limits of performance and a hierarchical understanding of the underlying causes of limited performance.

DESCRIPTION: Active optical (LIDAR) techniques exist to measure sound speed in liquids remotely by spectrally resolving the Brillouin component of the backscatter. In contrast to Raman LIDAR techniques, which require assumptions about salinity to derive sound speed, Brillouin LIDAR techniques are capable of inferring sound speed directly. However, demonstrations of the Brillouin technique have so far been confined to the laboratory, and are not routinely employed in the field, nor do commercial sensors exist.

Any approach offered shall, at a minimum, enable the measurement of sound speed profiles in seawater remotely, along a line of sight, day and night, with an accuracy of at least 1.5 m/s, and an along-beam resolution of 5 m or better, to a total range in mesotrophic waters of at least 40 m. The approach must not depend on assumptions about salinity or temperature of the water, nor the amount of suspended particulates, and must be fieldable and hands-free.

This effort is focused on exploring novel techniques that exploit the Brillouin scatter process to directly measure sound speed in water. Any approach must show early promise for enabling routine operational measurements from seagoing and/or airborne vessels, and must not depend on regular human intervention to operate correctly. Candidate techniques include, but are not limited to, use of stable optical filters, spectrometers, or combinations thereof, to spectrally resolve Brillouin backscatter.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and ONR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Define and develop a concept to obtain profiles of sound speed through seawater that is compatible with deployment on seagoing vessels. The concept shall include a high level description of the

hardware and associated algorithms, description of a water tank demonstration, and corresponding performance simulations. All assumptions made for the performance modeling shall be clearly stated. Develop a Phase II plan.

PHASE II: Produce a laboratory water tank demonstration based on the Phase I work. The prototype shall demonstrate the form and function of the critical sensor elements as accurately as possible. The prototype shall be capable of validating key sensor performance parameters; laboratory validations shall be conducted and documented by the awardee using the prototype hardware. Sensor shall be delivered to the Government for testing.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Interface with stakeholders in both ocean modelling and tactical communities to identify platform (ship, submersible, etc.) and performance needs, then scale and engineer the system appropriately to those needs.

REFERENCES:

1. Hostetler, Chris A., Behrenfeld, Michael J., Hu, Yongxiang, Hair, Johnathan W. and Schulien, Jennifer A. "Spaceborne LIDAR in the study of marine systems." Annual review of marine science 10, 2018, pp. 121-147. <https://www.annualreviews.org/doi/pdf/10.1146/annurev-marine-121916-063335>
2. Englert, Christoph R., Harlander, John M., Brown, Charles M., Marr, Kenneth D., Miller, Ian J., Stump, J. Eloise and Hancock, Jed et al. "Michelson interferometer for global high-resolution thermospheric imaging (MIGHTI): instrument design and calibration." Space science reviews 212, no. 1-2, 2017, pp. 553-584. <https://ui.adsabs.harvard.edu/abs/2017SSRv..212..553E/abstract>
3. Mountain, Raymond D. "Spectral distribution of scattered light in a simple fluid." Reviews of Modern Physics 38, no. 1, 1966, p. 205. <https://doi.org/10.1103/RevModPhys.38.205>
4. Englert, Christoph R., Babcock, David D. and Harlander, John M. "Doppler asymmetric spatial heterodyne spectroscopy (DASH): concept and experimental demonstration." Applied Optics, Volume 46, Issue 29, 2007, pp. 7297-7307. <https://www.osapublishing.org/ao/abstract.cfm?uri=ao-46-29-7297>
5. Joelson, Brad D., and Kattawar, George W. "Multiple scattering effects on the remote sensing of the speed of sound in the ocean by Brillouin scattering." Applied Optics, Volume 35, Issue 15, 1996, pp. 7297-7307. <https://www.osapublishing.org/ao/abstract.cfm?uri=ao-46-29-7297>

KEYWORDS: LIDAR; Brillouin; sound speed; Doppler; back-scatter; spatial heterodyne

N211-090 TITLE: Refrigerant Vapor Quality Sensor

RT&L FOCUS AREA(S): Directed energy; General Warfighting Requirements

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a low-cost, high-speed sensor and instrumentation to measure refrigerant quality in an electronics cooling system.

DESCRIPTION: Two-phase cooling systems using pumped refrigerant loops are being developed to remove heat from high-powered electronic systems. These thermal systems would benefit from monitoring the relative mass fractions of liquid and vapor phases (quality) in a saturated mixture, for future system optimization and assurance of safe operation in harsh environmental and transient operational conditions. Capacitance and impedance techniques can be used for volume averaged void fraction measurements, but these techniques are limited by their relatively low spatial resolution and the accuracy of the reconstructed image, and are not readily available to utilize for platform applications. Laboratory experiments rely on complex, expensive instrumentation to measure quality, such as image analysis or liquid-vapor separators. Measurement of the spatial and temporal variation of quality also allow for a characterization of flow regimes, which can be used to predict heat transfer performance. Such techniques are not easily translated to fielded systems that may require hundreds of such sensors operating at frequencies greater than 100 Hz for integration into the control system.

The goal of this SBIR topic is to design and fabricate a non-invasive, high-speed instrument to measure refrigerant quality in an operational, military electronics cooling system. The electronics cooling system shall be able to use the instrument measured refrigerant quality as a controls parameters. The instrument shall be able to assess vapor qualities as high as 0.80 and operate under dynamic platform motion as defined by DOD-STD-1399/301a. The instrumentation shall be waterproof and vibration resistant and should be able to interface with control systems through standard software communication protocols such as Modbus.

PHASE I: Develop a design for an instrument to measure refrigerant vapor quality. The sensor should not exceed 25 lbs per-unit-weight and 1 cu ft volume size. Validate design performance through analytical modeling and subscale demonstration for vapor qualities up to 0.80. Ensure that the system maintains proper operation when subjected to ship motion dynamics (DOD-STD-1399/301a). Perform rough manufacturing cost analysis. Develop a Phase II plan.

PHASE II: Refine Phase I design and fabricate prototype instrument, including software interface to commercial platforms. Ensure that the system is capable of monitoring at least 10 independent sensors. Demonstrate operation in a pumped refrigerant loop using R134a over vapor qualities of 0.0 to 0.80. Perform more detailed manufacturing cost analysis.

PHASE III DUAL USE APPLICATIONS: Develop final design and manufacturing plans using the knowledge gained during Phases I and II in order to support transition of system to Navy platforms. Ensure that the final system meets Navy unique requirements, e.g., shock, vibration, and electromagnetic interference (EMI). The development of refrigerant quality sensors capable of operating under dynamic motion associated with shipboard installation has commercial applications that include cooling of electric vehicles and commercial vessels.

REFERENCES:

1. Caniere, H., T'Joel, C., Willockx, A. and De Paepe, M. "Capacitance signal analysis of horizontal two-phase flow in a small tube." *Exp. Thermal Fluid Sci.* Volume 32, Issue 3, 2008, pp. 892–904. <https://www.sciencedirect.com/science/article/pii/S0894177707001550>
2. Valiorgue, P., Ritchey, S.N., Weibel, J.A. and Garimella, S.V. "Design of a non-intrusive electrical impedance-based void fraction sensor for microchannel two-phase flows." *Meas. Sci. Technol.* 25, 095301, 2014. <https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1237&context=coolingpubs>
3. Roman, A.J., Kreitzer, P.J., Ervin, J.S., Hanchak, M.S. and Byrd, L.W. "Flow Pattern Identification of Horizontal Two-Phase Refrigerant Flow Using Neural Networks." *Int. Comm. Heat Mass Transfer* 71, 2016, pp. 254-264. <https://apps.dtic.mil/dtic/tr/fulltext/u2/1007772.pdf>
4. Department of the Navy, Naval Sea Systems Command, DOD-STD-1399/301a, "Ship Motion and Attitude." (21 July 1986). <https://fddocuments.us/document/dod-std-1399-301-ship-motions.html>

KEYWORDS: Electronics Cooling; Two-Phase Cooling System; Vapor Quality; Pumped

N211-091 TITLE: Real-time Simulation of Radio Frequency (RF) Signal Returns from Complex Targets and Backgrounds

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Information Systems; Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a capability for high resolution real-time simulation of targets and cluttered backgrounds for active imaging Radio Frequency (RF) sensors during hardware-in-the-loop testing.

DESCRIPTION: Government hardware-in-the-loop (HWIL) facilities are used to evaluate closed-loop processes associated with weapon guidance and control. To close the guidance loop, the facility must realistically represent the input to sensors used to recognize, track, and guide to the target. In order to develop and test increasingly advanced radar seeker capabilities, there is a need to increase the resolution of the simulated RF scenes. One method of accomplishing this is by increasing the number of RF scatterers used to represent the RF scene. Imaging RF sensors using synthetic aperture radar technology might need on the order of one million scatterers to represent the complexity targets and background characteristics.

This SBIR topic focuses on the algorithmic processes and computing architecture required to generate high resolution scenes in a real-time hardware-in-the-loop test environment. The modified return pulses must be calculated and generated based on a dynamic engagement where the engagement parameters and radar state for each update are changing in real time. The scene processing will receive updated state information from the engagement simulation computer at a specified update rate (i.e., 1200Hz). An appropriate computing architecture must be found, possibly graphics processing unit (GPU), field-programmable gate array (FPGA), RFSOC, central processing unit (CPU), digital signal processor (DSP), or combinations of the aforementioned, that provides required increases in processing speed to modify the returned pulse based on target and background interactions. Algorithmic techniques must be defined and implemented to capture the effect of scattered energy in a complex scene (e.g., method of moments, ray tracing) compatible with the real time HWIL test environment. Urban and natural terrains will be bounded pretest, but may extend for considerable distances if used to obtain navigation reference information or if considerable target uncertainty exists.

There are two key steps in creating the return pulse waveform: 1) scene generation that has to occur once per pulse repetition interval (PRI) based on engagement kinematics, and 2) waveform generation that involves convolving the scene with the digitized transmit pulse which has to occur within the time of flight from the radar to the target area and back ($t = 2d/c$). The goal is the equivalent of 1 million scatterers in the target scene at 10,000 Hz. Note that the use of discrete scatterers to modulate the pulse is used as an example, with understanding that there may be other methods of capturing the effect of complex backgrounds.

The developed technology will be transitioned to Navy and other DoD facilities. For proof of concept and evaluation, the processing architecture must be baselined to communicate/interface with the existing 6DOF engagement systems and the Navy system located in existing facilities. A requirements assessment during Phase I will determine whether any additional interface compatibility is required for other government systems. Designs with modularity that allow for incremental increase in fidelity are possibly of benefit to accommodate budgetary and programmatic constraints. The Phase I effort will not require access to classified information. If needed, data of the same level of complexity as secured data will be provided to support Phase I work. The Phase II effort will likely require secure access, and SSP will process the DD254 to support the contractor for personnel and facility certification for secure access.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Bound the problem and develop a processing architecture that can meet the RF scene complexity/resolution goal. Attention will be paid to the best processing architecture or combinations of architectures that best meets the requirements. Document the design and trades made to reach the conclusions. Digital simulations should be executed to demonstrate the capabilities of the design. The software design should use best practices to provide for readability, modification, scalability, reproducibility and support constant evolution into new hardware (H/W) to allow for protection from obsolescence. A facility survey will be performed to determine compatibility requirements with relevant RF target simulators.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a prototype RF target simulation processing system and deliver for testing and evaluation as a component of the Navy Dynetics system. The prototype shall be based on the results of Phase I and the Phase II Statement of Work (SOW). The prototype shall be software (S/W) that runs on the existing Navy H/W, H/W that interfaces with the existing RF simulator hardware, or shall be some combination of both. Work with Navy subject matter experts, which may include Government personnel and contractors, to develop and demonstrate the prototype with the Navy RF simulator. Fully document the prototype design H/W, S/W and interfaces. The Government will provide the RF sensor and also develop a scenario or group of scenarios to act as test cases to be use to evaluate new scene generation capabilities. Collaborate with the Government to analyze the results of the test cases.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to DoD use. In addition to the Navy system, other DoD and DoD contractor facilities will be identified as potential recipients of this technology. The final product shall be a processing architecture that can generate high resolution RF scenes that are calculated in real-time and interface with DoD facilities. The system needs to be fully supportable and maintainable by the government. The system needs to be adaptable and expandable as technology improves.

This technology can be used to support non-DoD industries such as automotive radar, survey and mapping equipment manufacturing, and simulation for Geographic Information Systems (GIS) satellite radar manufacturers.

REFERENCES:

1. Balz, T. "Real-time SAR simulation of complex scenes using programmable graphics processing units." Proceedings of the ISPRS TCVII Mid-term Symposium, July 2006.
https://www.researchgate.net/publication/200148298_Realtime_SAR_simulation_of_complex_scenes_using_programmable_Graphics_Processing_Units
2. Zhang, F.C. "A GPU Based Memory Optimized Parallel Method For FFT Implementation."23 July 2017. <https://arxiv.org/pdf/1707.07263.pdf>

KEYWORDS: Synthetic target scene generation; Real-time RF Target Generation; Synthetic Aperture Radar SAR; Real-time SAR simulation; Radar Scatterers; Simulation of radar returns; Radar background modeling; RF target models

N211-092 TITLE: Onboard Flight Ablation Sensor

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Electronics; Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a sensor that can be integrated onboard a missile system to measure real-time surface temperature and ablation material response during hypersonic flight tests.

DESCRIPTION: A major technical challenge for hypersonic missiles includes managing the extreme heating environments experienced at hypersonic speeds. Current hypersonic systems have a Thermal Protection System (TPS) that includes expensive materials that are also difficult and time consuming to produce. Understanding the performance of these materials during developmental flight testing is key to providing an optimized system solution that can ultimately meet performance requirements while also reducing the cost to the US Government.

Critical TPS performance metrics that are required for full missile system performance in a flight test event include TPS surface temperatures and ablation data on critical components such as the nosecone, aeroshell and leading edges. Currently, sensor technology exists with the ability to capture critical TPS material information, including surface temperatures and ablation data, during laboratory testing. However, this sensor technology in its current state is not able to measure these parameters on a missile traveling at hypersonic speeds. The U.S. Navy is interested in a sensor that can be integrated onboard a missile system to measure real-time surface temperature and ablation material response during hypersonic flight tests.

This technology must be able to detect and measure parameters of the surface materials on the TPS from inside the missile. The design of the sensor will be required to have precise technical functionality as well as overcome the mechanical packaging and electrical integration challenges associated with an onboard missile system. This technology will enable critical test performance metrics to be captured that are not currently captured. The data collected from this enabling technology is critical to TPS modeling and simulation to further understand the capability of the current TPS design as well as future designs. This technology supports advanced system performance assessments such as understanding the maximum range capability of the current system. Also, this technology is key to reducing the robustness of the current TPS design in favor of an optimized design that focuses on system weight savings while maintaining performance requirements.

The Phase II effort will likely require secure access, and SSP will process the DD254 to support the contractor for personnel and facility certification for secure access. The Phase I effort will not require access to classified information. If needed, data of the same level of complexity as secured data will be provided to support Phase I work.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Propose a solution for developing a sensor that can be integrated onboard a missile system to measure real-time surface temperature and ablation material response during hypersonic flight tests. Identify ablation sensor technology and demonstrate bread-board ability to resolve length change on representative material. Perform subsystem design and analysis addressing material and environmental requirements for the sensor. Specific requirements for ablator material and measurement implementation for the prototype design must be understood. Demonstrate a concept that can maintain mechanical and electrical packaging requirements given by the Government upon contract award during the Phase I period of performance. The concept must be able to detect parameters on the materials surface from inside the missile.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a prototype that meets the Government's design requirements based on the results of Phase I and the Phase II Statement of Work (SOW) . The developed units must be suitable for proof-of-concept demonstration and ensure the electronic devices used on the prototype are suitable for flight test environments. During this Phase, access to classified design data is required to gain the actual system requirements for the technical specifications of the sensor, as well as the exact mechanical and electrical constraints that the prototype must adhere to. A Phase II Option, if exercised, would require the conduction of an aerothermal ground test with the prototype to prove that the performance and integration requirements of the prototype have been achieved.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Qualify the prototype to system level vibration and shock environments. Develop and document assembly instructions for the Government and provide assembly training on a test unit. Implement the technology for Conventional Prompt Strike (CPS) developmental flight testing then utilized further on other Navy flight systems as required.

REFERENCES:

1. Sherman, M.M. "Erosion Resistant Nosetip Technology." PDA Inc. Santa Ana, CA: PDA Technical Report, PDA-TR-1031-90-58, January 1978.
https://www.researchgate.net/publication/235198410_Hardened_Reentry_Vehicle_Development_Program_Erosion-Resistant_Nosetip_Technology
2. Papadopoulos, G., Tikiakos, N. and Thomson, C. "Real-Time Ablation Recession Rate Sensor System for Advanced Reentry Vehicles." 50th AIAA Aerospace Sciences Mtg, Nashville, TN, January 2012. <https://arc.aiaa.org/doi/10.2514/6.2012-531>

KEYWORDS: Hypersonic ablation; Thermal Protection System; Real-time surface temperature; Ablation material response; Hypersonic recession; Sensors

N211-093 TITLE: Real Time Single-Shot AI Enhanced Coherent Wavefront Sensing for Intelligence, Surveillance, and Reconnaissance (ISR) and Directed Energy Applications

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Sensors; Weapons

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OBJECTIVE: Develop a real-time computational pipeline that meets the demanding latency and throughput requirements for real-time single-shot artificial intelligence (AI) enhanced accurate wavefront sensing in imaging and directed energy applications.

DESCRIPTION: The phase distortions caused by the propagation of coherent light through deep layers of atmospheric turbulence create fundamental physical limitations for the problems of both optical imaging and directed energy (DE) in long-range air-to-ground and ground-to-air applications. As coherent light passes through many layers of atmospheric turbulence, the wavefront is distorted in a way so that a traditionally formed image is blurred with a space-variant distortion. Emerging methods in digital holographic (DH) imaged together with the fusion of advanced AI methods with advanced physics-based sensor models offer the possibility of recovering a model of the propagation distortion, so that the wavefront can be corrected. However, in order for these technologies to have impact, novel algorithms and integrated software/hardware systems must be created and implemented that allow for real-time closed-loop recovery and correction of optical wavefront distortion from a single-shot of data.

This SBIR topic looks to develop a volumetric wavefront sensing (WFS) computational pipeline that meets the latency, throughput, and accuracy requirements required for integration into a real-time imaging (i.e., Intelligence, Surveillance, and Reconnaissance (ISR)) or directed energy system. The end goal of this SBIR topic is to design (Phase I) and demonstrate (Phase II) a volumetric WFS prototype computational pipeline that can operate in the presence of extended non-cooperative targets and distributed-volume aberrations. The Phase I effort shall develop the integrated theoretical algorithms, software, and computational hardware systems required to meet the demanding throughput and latency requirements of closed-loop volumetric-wavefront sensing for both imaging and DE applications. The Phase II effort shall then implement these approaches in a prototype demonstration system to achieve the target performance on a scaled-laboratory optical system.

The outcomes of the proposed work are:

- 1) Integrated theoretical algorithms, software and computational hardware systems that can meet the throughput and latency requirements of closed-loop volumetric-wavefront sensing for both imaging and DE applications; and
- 2) A demonstrated prototype system, which can achieve the specified target performance on a scaled-laboratory optical system.

The Phase I effort will not require access to classified information. If needed, data of the same level of complexity as secured data will be provided to support Phase I work. The Phase II effort may require secure access; if so, SSP will process the DD254 to support the contractor for personnel and facility certification for secure access.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Create theoretical methods for integrating AI with coherent optical sensor models for accurate estimation of volumetric phase distortion in long-range imaging and DE applications. Perform feasibility analysis of software/hardware pipeline for real-time implementation meeting latency and throughput requirements. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Build an integrated algorithmic, software, and hardware prototype system that performs low latency and high throughput computation of accurate wavefront parameters for compensation in imaging and DE applications. Demonstrate real-time system performance on a scaled-laboratory optical system.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Developing a real-time computational pipeline with real-time single-shot AI enhanced accurate wavefront sensing can be applied to other systems associated with long-range missions at increased speeds that utilize imaging and directed energy applications.

REFERENCES:

1. Pellizzari, Casey; Spencer, Mark; and Bouman, Charles. "Coherent-Image Reconstruction Using Convolutional Neural Networks." Optical Society of America (OSA) Imaging and Applied Optics Congress, 24-27 June 2019. <https://www.osapublishing.org/viewmedia.cfm?uri=MATH-2019-MTu4D.4&seq=0>
2. Pellizzari, Casey; Spencer, Mark; and Bouman, Charles. "Imaging Through Distributed-Volume Aberrations using Single-Shot Digital Holography." The Journal of the Optical Society of America A (JOSA-A), 36.2, 1 February 2019, pp. A20-A23. <https://engineering.purdue.edu/~bouman/publications/orig-pdf/josaa-36-2-A20.pdf>
3. Pellizzari, Casey; Spencer, Mark; and Bouman, Charles. "Demonstration of single-shot digital holography using a Bayesian framework." The Journal of the Optical Society of America A (JOSA-A), 35.1, 1 January 2018, pp. 103-107. <https://engineering.purdue.edu/~bouman/publications/orig-pdf/josaa8.pdf>
4. Pellizzari, Casey; Spencer, Mark; and Bouman, Charles. "Phase-Error Estimation and Image Reconstruction from Digital-Holography Data using a Bayesian Framework." The Journal of the Optical Society of America A (JOSA), 34.9, 1 September 2017, pp. 1659-1669. <https://engineering.purdue.edu/~bouman/publications/orig-pdf/josa7.pdf>
5. Pellizzari, Casey; Trahan, Russell; Zhou, Hangying; Williams, Skip; Williams, Stacie; Nemati, Bijan; Shao, Michael; and Bouman, Charles. "Optically-Coherent Image Formation and

Denoising Using Plug and Play Inversion Framework.” Applied Optics 56.16, 1 June 2017, pp. 4735-4744. <https://engineering.purdue.edu/~bouman/publications/orig-pdf/AO3.pdf>

KEYWORDS: Digital Holography; Coherent optical sensing; Wavefront sensing; Deep turbulence; Anisoplanatic turbulence; Adaptive optics; Beam control; Artificial Intelligence; Deep Neural Networks.

N211-094 TITLE: Compact Phase Locked Laser System for Atom Interferometric Inertial Sensors

RT&L FOCUS AREA(S): Nuclear Modernization

TECHNOLOGY AREA(S): Electronics; Materials / Processes; Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a compact and low power laser system capable of agile generation of all light frequencies required in an atom interferometry application. Demonstrate that the lifetime of all lasers in the optical system is sufficient to support extended periods of operation before required maintenance, and characterize robustness of the system to shock and vibration input.

DESCRIPTION: Light pulse atom interferometry (LPAI) [Ref 1] has been used to perform the most sensitive inertial measurements to date. It is emerging as a candidate technology for inertial sensors (such as gravimeters, accelerometers, and gyroscopes) with unprecedented performance. One obstacle for the development of atom interferometers is the need for further development of compact, robust, and stable laser systems that are capable of producing the requisite laser frequencies for LPAI as well as performing the ancillary functions of atom cooling, state preparation, and state readout.

Compact and robust laser systems for atom interferometry will facilitate the adoption of this technology in multiple application areas including inertial guidance and navigation and gravity mapping. Shipboard navigation using gravity measurements [Ref 2] to aid a traditional inertial navigation system is a typical use case. These systems may also find use in geophysical surveys for resource exploration.

These systems must also have the capability for fast frequency adjustment and shuttering on microsecond timescales. One promising approach is to perform these functions using a number of separate laser sources (such as Distributed Feed Back (DFB)) that are mutually offset-phase locked to a frequency stabilized master laser. The use of agile phase locking enables each output frequency to be adjusted throughout the measurement cycle while enabling the generation of phase-stable Raman pairs for LPAI while reducing the reliance on optical modulators that can be a driver of system power consumption. The Navy's need is the further development and testing of compact phase-locked laser sources to ensure they can maintain sufficient phase stability for LPAI, can be tuned over 1 GHz repeatedly in a measurement cycle, support long laser lifetimes, and are capable of recovery from shock and vibration.

PHASE I: Develop a design for a compact laser system meeting the following requirements:

- Master laser locked to a saturated absorption feature of an alkali D line
- Two slave lasers phase locked to the master with offsets ranging from 0 to 5GHz
- Over 50 mW output power in each frequency component
- Capable of switching between multiple offset frequencies with switching time under 1ms
- Volume of optical module under 50 c.c. (not including drive electronics)
- Power consumption under 3W

Perform a study of laser lifetimes using laser sources similar to those in the proposed design. Develop a roadmap for achieving system lifetime over 50000 hours. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Build a prototype laser module with support electronics meeting the requirements for the design developed in Phase I. Characterize per MIL-STD-810 [Ref 3] for the response of the module to mild vibration and shock inputs. Perform a study of laser lifetimes using similar laser sources to characterize the expected lifetime of the module. Deliver the prototype by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Compact and robust laser systems for atom interferometry will facilitate the adoption of this technology in multiple application areas including inertial guidance and navigation and gravity mapping. Shipboard navigation using gravity measurements [Ref 2] to aid a traditional inertial navigation system is a typical use case. These systems may also find use in geophysical surveys for resource exploration.

REFERENCES:

1. Kasevich, M. and Chu, S. "Atomic interferometry using stimulated Raman transitions." Phys. Rev. Lett. 67, 181, 1991. <https://doi.org/10.1103/PhysRevLett.67.181>
2. Bidel, Y. et al. "Absolute marine gravimetry with matter-wave interferometry." Nature Communications volume 9, Article number: 627, 2018. <https://doi.org/10.1038/s41467-018-03040-2>
3. "Environmental Engineering Considerations and Laboratory Tests." ASSIST-QuickSearch Document Details. 2020. https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=35978

KEYWORDS: phase locked laser system; atom interferometry; inertial sensor; laser; navigation; image sensor

N211-095

TITLE: Age Effect Evaluation: Test Methodology

RT&L FOCUS AREA(S): Nuclear Modernization

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an innovative approach to measure aging effects on electronics piece parts accurately, with an ability to predict the degradation in electrical performance of deployed electronics in the fleet.

DESCRIPTION: Strategic Systems Programs (SSP) needs an innovative approach of testing hardware to expediently gain insight on effects of aging on electronic piece parts (including MicroElectrical Mechanical (MEM) sensors) on current missile systems, in lieu of typical life test approach. Current methods implemented in the program, and those currently used in the industry, are typically time-consuming. Typical present reliability techniques subject a part to elevated temperatures for a period of time to accelerate the aging mechanism. Electrical measurements are (1) functionality, (2) AC parameters, and (3) DC parameters, combined with radiation testing and destructive analysis to determine any alterations in the radiation response and doping process. These techniques are not usually perceptive to small changes in a device. Usually the measurements are taken from outside the part (higher resolution) and the equipment used do not have adequate resolution or sensitivity to discriminate electrical changes within the device itself.

The following potential methods are far more superior than previous techniques. They use advanced technology approaches; are far more sensitive than previous methods; and use real-time measurements. Some are noninvasive. This SBIR topic seeks research to apply these methods and determine the sensitivity of these techniques to changes in a semiconductor or electronic component due to aging. A method of transmitting the measurements to a monitoring system will also need to be developed.

- (1) A more advanced noninvasive technique should evaluate an accurate sensor, using solid state electromechanical technologies. [Refs 1,2]
- (2) Another method could be to develop a radio frequency (RF) technique to evaluate the aging effects based on the detection of electromagnetic signature changes from a device. [Refs 3, 4]
- (3) Another acceptable approach should consider an electrical measurement that could detect 1 ppm changes or better with advanced semiconductor technologies. [Ref 5]

Aging of electronics that affect the radiation hardness of a device is a concern. Two effects are (1) Negative Bias Temperature Instability (NBTI) affecting p channel transistors in advanced Complementary Metal-Oxide-Semiconductor (CMOS) technologies less than 300 nm in feature size, and (2) gold ion diffusion impacting the dose rate threshold performance of a part. The first effect can be monitored via a p channel transistor that can be integrated on the same device. To maximize the sensitivity of detection, different sizes of p channel transistors, channel length and width dimensions would need to be fabricated and tested for NBTI. The second effect is more challenging to measure.

Typically, one would irradiate a part at a prompt dose rate facility like an electron beam accelerator or a Flash X-ray machine. Another technique has been to expose a part to a laser tuned to penetrate into the substrate of the part and measure the upset threshold of the part. The upset threshold is compared with a “Gold” standard such as one that did not have gold diffusion or has been aged.

The proposed R/D effort is to determine a method of detecting the movement of gold from the die attachment substrate into the silicon bulk substrate and quantify the location of these gold atoms. The spatial resolution needs to be 5 micron or better. One possibility is to leverage on medical imaging techniques used in identifying cancer tumors or in detecting blood clots as in X-ray tomography or radiography. Gold and silicon vary vastly in mass absorption, so the detection of gold is easy with X-rays. Neutron radiography is another approach used in the detection of banned weapons of mass destruction. These are some of the techniques that would be examined to determine the spatial resolution and the sensitivity to identifying the movement of a gold atom in silicon.

PHASE I: Define and develop the concept(s) for a test approach(es) or method(s) that will accurately and expediently (80% of typical duration of current/standard tests defined in the applicable standards/specifications for each part technology) measure the aging effects on electronics piece parts as defined in the Description. Provide description(s) of the approach(es), along with corresponding preliminary evidence supporting each approach. Validate the method selected. Identify technical challenges as well as risks and opportunities for the selected method that will be addressed during Phase II. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II. Prepare a Phase II plan.

PHASE II: Develop a physical prototype of the proposed test approach or method that meets the capabilities listed in the Description. Demonstrate and validate the test approach or method. Demonstrate the ability of the prototype to meet or exceed the accuracy of current test method results. Identify, document, and demonstrate the time reduction achieved by using the prototype over standard life testing. Identify and document any opportunities for improvements for future iterations.

PHASE III DUAL USE APPLICATIONS: Support in transitioning the technology for Navy use in SSP. Support the Navy with certifying and qualifying the system for SSP use. Navy SSP will provide the assets and test support as Government Furnished Equipment and Services. The accelerated age assessment evaluation test method will be adopted for use in evaluating electronic piece parts currently deployed in missiles. The technology developed can be commercialized into the automotive industry electronics where such devices could be used to determine when a car begins to have aging problems. Another area would be in the commercial airline industry to help diagnose the degradation of aging electronics. Other areas include embedding smart chips either within appliances, smart phones, security systems, and commercial transportation systems to monitor their health. With the miniaturization of microchips, we are seeing the utilization of these devices in humans as well as in electronics to monitor the vital signs and to detect changes rapidly and invasively in an affordable way.

REFERENCES:

1. Kalgren, P.W., Ginart, A.E., Nanduri, S. et al. “Systems and Methods for Predicting Failure of Electronic Systems and Assessing Level of Degradation and Remaining Useful Life.” U.S. Patent 8103463B2. <https://patents.google.com/patent/US8103463B2/en>
2. “Fabrication of advanced silicon-based on MEMS devices.” Analog Devices, U.S. Patent EP1452481B1. <https://patents.google.com/patent/EP1452481B1/en>
3. Keller, W., Freeman, S.D. and Galyardt, J. “System and method for physically detecting counterfeit electronics.” U.S. Patent 20120226463A1. <https://patents.google.com/patent/US20120226463A1/en>

4. Pauly, G.W. and Keller, G.W. "Advanced Manufacturing Monitoring and Diagnostic Tool." U.S. Patent 8643539B2. <https://patents.google.com/patent/US8643539B2/en>
5. Newman, P.F. "Leakage Oscillator Based Aging Monitor." U.S. Patent 7,592,876. <https://patents.justia.com/patent/7592876>

KEYWORDS: MEM; MicroElectrical Mechanical Sensors; NBTI; Negative Biased Temperature Instability; Sensors; Age Effects; Material Age Testing; Electronic Materials

N211-096

TITLE: Producibile Radiation-hardened Interconnects Technology

RT&L FOCUS AREA(S): Nuclear Modernization

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop and evaluate cable manufacturing techniques and compatible connectors that are easy to produce, reliable, and can function in strategic radiation environments. Designed with lifecycle and maintenance costs in mind. Designed with producibility/manufacturability in mind.

DESCRIPTION: With a new ballistic missile submarine under development (OHIO-Replacement Class SSBN), the capability delivered by the Trident II (D5) missile will be needed into the 2080s. Current D5 missile performance will remain a top priority for life extension efforts while achieving Navy Strategic Systems Programs (SSP) affordability objectives. Currently, hand-built filled and unfilled cables are used, which represent a significant production cost for D5. Finding approaches to improve the producibility of radiation hardened cables and connectors while reducing the impact of nuclear-event induced effects on electronics has the potential for reducing program lifecycle costs.

Missile modernization will result in avionics architectures that are highly data bus-centric, with electrical connections consisting primarily of power lines and data lines. Such data bus-centric designs require higher data rates over longer distances and require unique interconnect (cables and connectors) interfaces to achieve maximum data transmission while operating in a harsh environment. Operation in a nuclear environment imposes many design challenges, one of which is reducing cable System Generated Electromagnetic Pulse (SGEMP) effects on interface electronics. Current cable designs reduce SGEMP/radiation; however, fabrication is labor-intensive and difficult to replicate in large quantities, since they are hand-built. Because all conductors are point-to-point copper wire throughout the missile, the current design carries a high weight penalty. Producibility and manufacturing repeatability of radiation-hardened interconnects are the subjects of this SBIR topic. An ideal solution must be efficient, reliable, and meet the requirements defined below.

Using readily available and common interconnect hardware across the Avionics subsystem will reduce interconnect complexity, thereby reducing overall cost. Rigid flex cabling, fiber optic cabling, and new, robust cable manufacturing techniques must be considered for potential applicability.

Requirements of the solution:

- Data transmission rates in excess of 100Mbps (Goal of 10 Gb/s)
- Radio Frequency (RF)/Electromagnetic Interference (EMI)/SGEMP shielding protection (radiation-hardened)
- Ruggedness/space flight environment survivability (nuclear, shock, vibration, extreme heat, temperature/humidity cycling)
- Ease of integration with small form factor and RF-sensitive electronics
- Design architecture flexibility (low and high current capacity, modular, easily-adaptable interconnects)

Current technology analysis includes:

- Feasibility of modern printed circuit “Flex Cable” manufacturing techniques for missile applications.
 - o Maximum “Flex Cable” length practical with current manufacturing techniques
 - o Feasibility of using “Trapped Electron Reduction cable” SGEMP control techniques, or other alternatives, in Flex cabling
 - o Feasibility of Incorporating SGEMP terminal protection means (e.g., resistors, caps, diodes) in cable itself
 - o Ability to support high speed data (>100Mbps) over 40 feet with SGEMP mitigations
 - o Effectiveness of SGEMP control techniques
 - o Producibility and cost assessment relative to alternatives
- Discrete Wire cable techniques (e.g., Trapped Electron Reduction cable [Ref 4]) and potential limitations
 - o Incorporate SGEMP terminal protection means (e.g., resistors, caps, diodes) in cable itself
 - o Ability to support high speed data (>100Mbps) over 40 feet with proposed SGEMP mitigations
 - o Effectiveness of SGEMP control techniques
 - o Producibility and cost assessment relative to alternatives
- Fiber/Ethernet/Datalink for high speed data communications and potential limitations
 - o Application considerations in a Strategic Missile environment
 - o Radiation darkening of fiber
 - o Fiber connector contamination concerns/mitigation
 - o Fiber Transmitters/Receivers survivability for Strategic radiation-hardened environments
 - o Explore inclusion of fiber with copper in same cable to reduce cable quantity
 - o Producibility and cost assessment relative to alternatives
 - o Effectiveness of SGEMP control techniques
 - o Maintenance cost risk associated with repair/rework/replace compared to traditional copper
 - o Consider and assess existing high bandwidth/speed cable options (i.e., fiber vs. Ethernet vs. Datalink) and assess risks/tradeoffs
- Analysis of new/emerging technologies, to include:
 - o Ultra-miniature connectors that provide robust capability in smaller form factor
 - o Ability to integrate high speed data transmission contacts with traditional copper contacts
 - o Explore options in connector grommet seal techniques/processes to reduce well-known fleet issues (e.g., silicone migration, damaged pins/tines, Foreign Object Damage (FOD) contamination)
 - o Producibility/repeatability of EMI-shielding techniques and processes
 - o Producibility of new connectors that meet or exceed the current solution functionality and reliability
 - o Alternate backshell/connector accessories. Current configuration requires special tooling and difficult processes

PHASE I: Develop approaches for the fabrication and production of radiation-hardened cables and connectors that reduce the effects of SGEMP while maintaining the performance characteristics of a high bandwidth interconnect for use in strategic missile environments. With the basic cable design understood, construct a decision matrix and analyze several feasible interconnect solutions. Utilize aforementioned analyses to begin connector down-select process. Ensure that the proposed approaches are low cost and use high-reliability interconnect hardware and simple, proven fabrication techniques.

Conduct a feasibility assessment for the proposed application, assessing benefits and drawbacks of various approaches that address, at a minimum, the capabilities/limitations listed in the topic description. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II. Develop a Phase II plan.

PHASE II: Fabricate and produce radiation-hardened interconnect prototype(s) in sufficient quantities to accomplish the following:

- Assess manufacturing costs, time constraints/limitations, and ease of consistent, controllable repeatability for scaling up to a future production environment.
- Simulate/test producible interconnects in relevant “Test Like You Fly” (TLYF) environments.
- Collect performance data that can be used to characterize feasibility and application for use over a long production lifecycle.

Prepare a Phase III development plan to transition the technology for Navy combat systems and potential commercial use.

PHASE III DUAL USE APPLICATIONS: Missile cables and interconnects will be manufactured, demonstrated, and transitioned into the missile and submarine. Provide support in transitioning the technology for Navy use in SSP. Support the Navy with certifying and qualifying the system for SSP use with assets and test support provided by the Navy as Government Furnished Equipment and Services.

Radiation-hardened interconnects required for Navy SSP that are developed under this SBIR topic will be applicable to many commercial satellite and rocket programs, especially in applications that have restrictive physical space and/or harsh EMI/Radiation environment requirements.

REFERENCES:

1. Maher, Michael. “AN-926 Radiation Design Considerations Using CMOS Logic.” Texas Instruments, National Semiconductor Note 926, January 1994.
<http://www.ti.com/lit/an/snoa254a/snoa254a.pdf>
2. Fang-Chichton, Su. US Patent 6,093,893 Radiation Hardened Electrical Cable Having Trapped-electron Reducers.
<https://patentimages.storage.googleapis.com/43/7a/07/afea80a66c2955/US6093893.pdf>
3. Girard, Sylvain et al. “Recent advances in radiation-hardened fiber-based technologies for space applications.” Journal of Optics 20, 2018. <https://iopscience.iop.org/article/10.1088/2040-8986/aad271/pdf>

KEYWORDS: Materials Development; Cables; Interconnect; Connectors; Production Techniques; Producibility; Radiation Hardened

N211-097

TITLE: Radar Seeker Model for Hypersonic Weapon Full Life Cycle Support

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Electronics; Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a high-fidelity design-level modeling environment for radar seeker subsystems that captures the relevant operational and environmental constraints of hypersonic flight. The model will be configurable to perform low level design tradeoffs in a standalone environment or operate as a subsystem in closed-loop 6DOF architectures for end-to-end integrated performance evaluation.

DESCRIPTION: In order to develop and simulate advanced radar seeker concepts at the extreme conditions associated with hypersonic flight, there is a need to develop a modeling capability that considers the mission-specific challenges for the potential seeker concepts. Government laboratories need a robust seeker modeling capability to perform research involving fundamental design tradeoffs for future concepts, as well as to efficiently predict operational performance. Seeker models are used at all stages of the weapon simulation process. In flight simulations of an integrated munition, the seeker may provide an alternative means of navigation and directly feed guidance, acquiring the target and selecting an aimpoint in the presence of target location error. For modeling and simulation to be relevant, DoD acquisition guidance stresses the need to continually refine the model based on results from experimental data collection. The acquisition trend toward validated “digital twins” further emphasizes the need for a high-fidelity seeker model operating with Radio Frequency (RF) that follows a concept from inception through operational deployment. The desire for conforming to Weapon System Open Architecture interface standards also benefits from high-fidelity models that allow the assessment of standard conformity and data validity.

Hypersonic weapons in particular provide challenges that stress the functional performance of the seeker subsystem. Current modeling tools do not integrate the effects of the aero-thermal and thermo-elastic impacts of the hypersonic environment on measurement accuracy. It is essential to model the impact of aerodynamic heating for specific radome/antenna placement and deformation of exotic airframes built of materials such as Inconel and titanium alloys. It is also important to model the in-depth heating, static deformation, and modal dynamics of the structure when they impact measurement accuracy. The ability to interface with Government-developed Fluid-Thermal-Structural-Interaction (FTSI) models, even during real-time hardware-in-the-loop simulation, is desired to capture the impact of the environment on guidance performance. The required tool should not only allow for front end design signal processing simulation, but also backend processes such as image formation and target identification. The ability to impart and assess the impacts of kinematic constraints on data acquisition and signal processing functions is essential. An RF sensor on a weapon that plans to use Synthetic Aperture Radar (SAR) or Doppler Beam Sharpening (DBS) will need to pick a different waveform than a sensor flying at more conventional speeds. RF seekers on weapons do not have the favorable squint angle of a side-looking radar and will be expected to operate in steep, extended, terminal dives. Conventional “stop and hop” radar models may

have errors when they assume the beginning of the transmit pulse and end of the receive pulse are close in space and the speed of the weapon is far from the speed of light.

The developed technology will be transitioned to Navy and other DoD facilities. For proof of concept and evaluation, the processing architecture must be baselined to communicate/interface with the existing 6DOF engagement systems, FTSI modeling capabilities, and radar scene modeling capabilities. Detailed knowledge of RF seeker design, seeker functional requirements in a munition environment, and hypersonic environmental constraints is critical. Understanding and modeling of the impact of emerging technologies will be required. A requirements assessment during Phase I will determine Use Cases and required interface compatibility with other government systems. Designs with software modularity that allow for incremental increase in fidelity are possibly of benefit to accommodate budgetary and programmatic constraints.

The Phase I effort will not require access to classified information. If needed, unclassified data of the same level of complexity as classified data will be provided to support Phase I work. The Phase II effort will likely require access to classified information, and SSP will process the DD254 to support the contractor for personnel and facility certification for secure access.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Establish Use Cases and develop a simulation architecture that can meet the RF seeker modeling goals identified. Physical models and dependencies will be determined along with fidelity requirements associated with each Use Case. Document the design and trades made to reach the conclusions. Design risks will be determined and to the extent possible proof of concept for the approach taken will be accomplished. The software design should use best practices to provide for readability, modification, scalability, maintenance, and verification. In Phase I, model limitations will be identified that need to be addressed during Phase II. Phase II objectives and demonstration plans will be identified. The Phase I Option if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a prototype model for a subsystem of a hypersonic seeker based on a hardware design. The prototype shall be based on the results of Phase I and the Phase II Statement of Work (SOW). The prototype shall be in a language such as C++ or other highly efficient, stable, executable form. The Government shall have access and full Government purpose rights to all source code. Work with Navy subject matter experts, which may include Government personnel and contractors, to develop and demonstrate the prototype and integrate this prototype into a standalone design environment and 6DOF simulation forms. Fully document the prototype design and interfaces. Work together with the Government to analyze the results of all models that are integrated into the hypersonic seeker model as it performs relevant hypersonic engagement scenarios and vignettes.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Navy and Air Force in transitioning the technology to DoD use. In addition to NSWC Crane and AFRL/RW, other DoD and DoD contractor facilities will be identified as potential users of this technology. The final product supports multiple applications from early conceptual design through mature validated digital representation of an operational seeker. The end product will allow evaluation of software changes and will allow for planning of mission compatibility of the seeker technology. The system needs to be fully supportable and maintainable by the government so that models can be moved between Use Cases for a given weapon system application. The system needs to be adaptable and expandable as technology improves. This technology can also be used to model other problems where high speed maneuvering with radar sensor data collection is needed. Example applications are collision avoidance and terrain mapping for both commercial airplanes and future autonomous cars.

REFERENCES:

1. Clive, Peter. "Advanced Framework for Simulation, Integrating, and Modeling (AFSIM)." International Conference on Scientific Computing (CSC'15). www.worldcomp-proceedings.com/proc/p2015/CSC7058.pdf
2. Director, Systems and Software Engineering Deputy Under Secretary of Defense (Acquisition and Technology) Office of the Under Secretary of Defense (Acquisition, Technology and Logistics). "Systems Engineering Guide for Systems of Systems", August 2008 (recently revised). acqnotes.com/wp-content/uploads/2014/09/DoD-Systems-Engineering-Guide-for-Systems-of-Systems-Aug-2008.pdf
3. Balz, T. "Real-time SAR simulation of complex scenes using programmable graphics processing units." Proceedings of the ISPRS TCVII Mid-term Symposium. https://www.researchgate.net/publication/200148298_Real-time_SAR_simulation_of_complex_scenes_using_programmable_Graphics_Processing_Units

KEYWORDS: Guidance, Navigation, and Control GNC; Advanced Framework for Simulation, Integration, and Modeling AFSIM; Synthetic Aperture Radar SAR; hypersonics; airframe modeling; RF seeker; RF image processing

N211-098

TITLE: Unconventional Navigation Approaches Using Signals of Opportunity

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Electronics; Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop navigation approaches that take advantage of non-Global Positioning System (GPS) signal of opportunity, both natural and man-made, to determine earth relative location.

DESCRIPTION: Current navigation systems are heavily reliant on GPS signal technology for both commercial and military applications. While GPS has become a pervasive technology for military uses, it has security and availability challenges. In recent years, the ability to compromise GPS has been demonstrated by adversaries using jamming techniques that interfere with military mission execution. The research on this SBIR topic is intended to explore alternative technology solutions that would utilize natural or man-made signals of opportunity that may be available throughout the world to provide navigation precision comparable to GPS. Proposed approaches should be appropriate for the high-velocity and challenging environmental conditions associated with hypersonic flight or low earth orbit. The proposed approaches must be demonstrated in analysis or simulation to be able to provide precision equaling that of GPS in all weather conditions, at high altitude, at high velocity (hypersonic speeds), and must be broadly applicable throughout the world. Additional challenges include consistent reliability and size, weight, and power that would be compatible with current and future weapon systems, and communicate signals similar to GPS output codes (PY-code and M-code). Research and development is needed to demonstrate the feasibility of natural and man-made signals to satisfy these requirements. The research should be conducted with the goal of designing and demonstrating a prototype navigation system, and as such a system design for the use of these alternate signals should be considered.

The Phase I effort will not require access to classified information. If needed, data of the same level of complexity as secured data will be provided to support Phase I work. The Phase II effort is anticipated to require secure access, and SSP will process the DD254 to support the contractor for personnel and facility certification for secure access.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Propose specific innovative solutions for an alternative navigation approach, as opposed to simply proposing to study the problem. Specific natural or man-made signals should be identified along with the approach used for meeting the requirements stated in the Description. Demonstrate the feasibility of the approach to provide required accuracy, and the usefulness to military applications, including those associated with hypersonic weapons and space. Provide mathematical descriptions of the physical processes and signal processing being performed. In addition, modeling and simulation should be used to demonstrate feasibility for required applications. The required sensing maturity and signal processing requirements should be addressed in light of future size, weight, and power requirements.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II. Develop a Phase II plan that includes a Phase II Statement of Work (SOW) that identifies a work plan that provides proof of concept that the technology has the potential to meet the military performance goals highlighted in Phase I.

PHASE II: Design and build a prototype with enough detail for development and demonstration of a navigation system based on the non-conventional signals addressed in Phase I. Use a combination of hardware, software, and modeling and simulation to maximize demonstration of feasibility to meet military objectives within the cost constraints of the program. Experimental data collection of the navigation signal sources is desired where appropriate and cost-effective.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the Government in transitioning the technology for Government use. The transitioned product is expected to be able to support current and future weapon and space systems, as well as a wide range of other air, land and sea-based systems. Commercial applications should be considered for transition (e.g., telecommunications, ocean transportation, commercial satellite and mapping systems). Depending on the technology, it may apply beyond navigation on earth. The primary objective of this project is for transition to defense contractors for high speed weapons and space systems. To meet these needs, maturation and packaging of the technology to meet practical size, weight, and power constraints will be required. Extreme environments may require special considerations to conform to airframe shape and shielding from the aerothermal environment.

REFERENCES:

1. Raquet, John F.; Miller, Mikel M.; and Nguyen, Thao Q. "Issues and Approaches for Navigation Using Signals of Opportunity." Proceedings of the 2007 National Technical Meeting of The Institute of Navigation, San Diego, CA, January 2007, pp. 1073-1080.
<https://www.ion.org/publications/abstract.cfm?articleID=7203>
2. McEllroy, Jonathan A. "Navigation Using Signals of Opportunity in the AM Trans-Mission Band." Master's Thesis, Air Force Institute of Technology, 2006.
<https://apps.dtic.mil/dtic/tr/fulltext/u2/a456511.pdf>
3. Shamaei Kimia, Khalife, Joe; and Kassas, Zaher M. "Exploiting LTE Signals for Navigation: Theory to Implementation." IEEE Transactions on Wireless Communications, Vol. 17, Issue. 4, April 2018. <https://ieeexplore.ieee.org/document/8255823>

KEYWORDS: Alternate navigation; nonconventional signals; pulsar; Low Earth Orbits (LEO) satellites; Positioning, Navigation, Timing (PNT); Guidance

N211-099

TITLE: Photon-Counting Image Sensors Using Complementary Metal-oxide Semiconductor (CMOS) Foundry Processes

RT&L FOCUS AREA(S): Nuclear Modernization

TECHNOLOGY AREA(S): Electronics; Materials / Processes; Sensors

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OBJECTIVE: Develop a high-density, high-speed image sensor using Complementary metal-oxide semiconductor (CMOS) foundry processes that is capable of photon counting without deep cooling, and is also strategically radiation-hardened, for use in star trackers.

DESCRIPTION: The performance requirements for star trackers used in strategic navigation applications continue to become more stringent, necessitating continued innovation for image sensor technologies. Examples of existing research on photon-counting image sensors can be found in the Refs 1-5. In terms of idealities, these image sensors should be capable of high-speed (>1000 frames per second), low-noise (sub-electron) readout in a photon-counting mode without the need for deep cooling; have high-density (approx. 1 μm) pixel pitch; be radiation-hard at strategic levels; have low power consumption, and be able to be fabricated using CMOS foundry processes.

PHASE I: Perform a design and performance modeling study aimed at image sensors with improved performance for strategic star trackers as compared to the current state of the art. Assess performance and environmental sensitivity of parameters including responsivity, speed, noise, and defective pixels; consider all aspects of fabrication; and justify the feasibility/practicality of the approach. A goal of quantum efficiency greater than 70% from 400 to 640 nm and read noise < 0.3 electrons RMS is desired. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Fabricate and characterize a small lot (up to a quantity of 3) of prototype image sensors. Characterization using EMVA1288 standard, shall comprise various parameters including responsivity, speed, noise, and defective pixels. The prototypes shall be delivered by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Continue development to lead to productization of image sensors suitable for star trackers. While this technology is aimed at military/strategic applications, image sensors are heavily used in numerous other applications. An image sensor that can meet the stringent performance requirements of strategic instrumentation is likely to bring value to many existing commercial applications. Commercial applications for low light imaging applications include spectroscopy, optical scattering, and quantum communications.

REFERENCES:

1. Fossum, E. R. "Modeling the performance of single-bit and multi-bit quanta image sensors." IEEE Journal of the Electron Devices Society, 1(9), 2013, pp. 166-174.

<http://ericfossum.com/Publications/Papers/2013%20Modeling%20Single%20Bit%20and%20Multi%20Bit%20QIS.pdf>

2. Ma, J.; Hondongwa, D.; and Fossum, E. R. "Jot devices and the quanta image sensor." 2014 IEEE International Electron Devices Meeting, December 2014, pp. 10-1.
<https://ieeexplore.ieee.org/document/7047021>
3. Ma, J. and Fossum, E. R. "A pump-gate jot device with high conversion gain for a quanta image sensor." IEEE Journal of the Electron Devices Society, 3(2), 2015, pp. 73-77.
<https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7006672>
4. Ma, J. and Fossum, E. R. "Quanta image sensor jot with sub 0.3 e-rms read noise and photon counting capability." IEEE Electron Device Letters, 36(9), 2015, pp. 926-928.
<http://www.ericfossum.com/Publications/Papers/2015%20IEEE%20EDL%20Jot%20Letter.pdf>
5. Gnanasambandam, A.; Elgendy, O.; Ma, J. and Chan, S. H. "Megapixel photon-counting color imaging using quanta image sensor." Optics express, 27(12), 2019, pp. 17298-17310.
<https://www.osapublishing.org/oe/fulltext.cfm?uri=oe-27-12-17298&id=413534>

KEYWORDS: image sensor; star tracker; navigation, Complementary metal-oxide semiconductor; foundry; radiation-hard

N211-100 TITLE: GPS Alternative for Reentry

RT&L FOCUS AREA(S): Nuclear Modernization

TECHNOLOGY AREA(S): Electronics; Nuclear Technologies; Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Perform research to identify position sensing solutions for times in endoatmospheric flight where Global Positioning System (GPS) is unavailable in a denied flight environment to improve navigation and fuzing. Reliance on GPS is not considered an acceptable option for use in tactical environments.

DESCRIPTION: Navigation and fuzing capability of reentry bodies improves by aiding the inertial system with external location information. There are times where GPS is unavailable and denied solutions are of increasing interest to the strategic community.

Proposals are solicited that address the following capabilities:

- Evaluate suitable technology for position observability in times of flight when GPS is unavailable in denied and GPS jammed/spoofed environments
- Develop concept implementation for <4-minute atmospheric reentry
- Design, build, lab test system prototype
- Improve fidelity of selected system design and perform lab test
- Assess other limiting factors and areas of concern

Proposed solutions should support the following:

- Radiation-Hardened Electronics (suitable for exo-atmospheric space environments including the South Atlantic Anomaly)
- System operation for up to 6-minute reentry time
- Reliable system dormancy of at least 25 years
- Capable leverage/use of existing power supply or the specifications and requirements of an alternative power solution

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Develop a proof of concept of a system able to provide accurate position observable to aid a current tracking technology in the place of GPS within the following parameters:

- Accurate to within 20 feet
- Accurate at sea level to 400,000 feet altitude
- Accurate at speeds up to at least Mach 4

Present the solution concept with the following support documentation through the Concept Development phase which should build confidence that the system can naturally mature in line with customer (Navy SSP) expectations to be ready for engineering development:

- Technology Assessment
- Operational Analysis
- Feasibility Experiments
- System CONOPS
- Functional Decomposition
- Functional Block Diagram
- Functional and Physical architecture
- Expected Performance

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Mature the proven concept into the engineering development phase and build a prototype or engineering unit. Create a test profile for laboratory testing, and display system performance capability. Provide deliverables that should include but are not limited to:

- Subsystem Definitions
- Component Specifications
- Component Test Results
- System Integration Interfaces

PHASE III DUAL USE APPLICATIONS: Demonstrate flight worthiness of prototype and produce a Flight Test Article, ready for integration into next higher assemblies. Support future production of units if the solution is selected to be incorporated into a larger system.

For commercial markets the satellite industry would be able to benefit from this technology.

REFERENCES:

1. Russell, J.S.; Ye, M.; Anderson, B.D.O.; Hmam, H. and Sarunic, P. "Cooperative Localization of a GPS-Denied UAV Using Direction-of-Arrival Measurements." IEEE Transactions on Aerospace and Electronic Systems, vol. 56, no. 3, June 2020, pp. 1966-1978. doi: 10.1109/TAES.2019.2942704
2. Pierrottet, D.F.; Amzajerdian, F.; Hines, G.D.; Barnes, B.W.; Petway, L.B. and Carson, J.M. "Lidar Development at NASA Langley Research Center for Vehicle Navigation and Landing in GPS Denied Environments." 2018 IEEE Research and Applications of Photonics In Defense Conference (RAPID), Miramar Beach, FL, 2018, pp. 1-4. doi: 10.1109/RAPID.2018.8508958

KEYWORDS: GPS Alternatives; Navigation; SAASM; LIDAR; Inertial Aiding; Hypersonic; Radiation-Hardened Electronics