

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

IMPORTANT

- **The following instructions apply to SBIR topics only:**
 - **N202-088 through N202-147**
- **The information provided in the DON Proposal Submission Instruction document takes precedence over the DoD Instructions posted for this Broad Agency Announcement (BAA).**
- **DON updates the Phase I Technical Volume (Volume 2) page limit to not exceed 10 pages.**
- 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 optional Supporting Documents Volume (Volume 5) is available for the SBIR 20.2 BAA cycle. The optional 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 period **6 May 2020 through 2 June 2020**. Beginning **3 June 2020**, the SBIR/STTR Interactive Technical Information System (SITIS) (<https://www.dodsbirsttr.mil/submissions>) listed in Section 4.15.d of the Department of Defense (DoD) SBIR/STTR Program Broad Agency Announcement (BAA) must be used for any technical inquiry. 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>
N202-088 to N202-090	Mr. Jeffrey Kent	Marine Corps Systems Command (MCSC)	jeffrey.a.kent@usmc.mil
N202-091 to N202-122	Ms. Donna Attick	Naval Air Systems Command (NAVAIR)	navairsbir@navy.mil

<u>Topic Numbers</u>	<u>Point of Contact</u>	<u>SYSCOM</u>	<u>Email</u>
N202-123	Mr. Timothy Petro	Naval Facilities Engineering Center (NAVFAC)	timothy.petro@navy.mil
N202-124 to N202-133	Ms. Lore-Anne Ponirakis	Office of Naval Research (ONR)	loeranne.ponirakis@navy.mil
N202-134 to N202-135	Mr. Shadi Azoum	Naval Information Warfare Systems Command (NAVWAR)	shadi.azoum@navy.mil
N202-136 to N202-147	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.

PHASE I PROPOSAL SUBMISSION REQUIREMENTS

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

- **Proposal Cover Sheet (Volume 1).** As specified in DoD SBIR/STTR 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).** Volume 4 is not available for the 20.2 BAA. Please refer to the DoD SBIR/STTR BAA section 5.4(e) for further information.
- **Supporting Documents (Volume 5).** The optional Volume 5 is provided for small businesses to submit additional documentation to support the Technical Proposal (Volume 2) and the Cost Volume (Volume 3). Volume 5 is available for use when submitting Phase I and Phase II proposals. A template for Volume 5 is available on https://navysbir.com/links_forms.htm. DON will not be using any of the information in Volume 5 during the evaluation.

Note: Even if you are not providing documentation within Volume 5, DSIP will require you to respond to a “yes” or “no” question regarding the volume. Failure to respond may stop you from submitting and certifying your proposal.

- Letters of Support relevant to this project
- Additional Cost Information

- SBIR/STTR Funding Agreement Certification
- Technical Data Rights (Assertions)
- 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

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 has implemented the optional Fraud, Waste and Abuse Training Certification (Volume 6). DON does not require evidence of Fraud, Waste and Abuse Training at the time of proposal submission. Therefore, DON will not require proposers to use Volume 6.

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 TABA providers in an amount not to exceed the values specified below. The Phase I TABA amount is up to \$6,500 and is in addition to the award amount. The Phase II TABA amount is up to \$25,000 per award. The TABA 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 TABA 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 TABA as part of one additional (sequential) Phase II award under the project for a total TABA award of up to \$50,000 per project.

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

- TABA provider(s) (firm name)
- TABA provider(s) point of contact, email address, and phone number
- An explanation of why the TABA provider(s) is uniquely qualified to provide the service
- Tasks the TABA 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 8.0 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 BAA Contracting Officer, or filed with the GAO. Contact information for the DoD SBIR/STTR 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 4.14.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

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).

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 Technical 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

NAVY SBIR 20.2 Topic Index

N202-088	Advanced Low-Level Parachute System
N202-089	Focused Enhanced Acoustic-Driver Technologies (FEAT) for Long Range Non-Lethal Hail and Warn Capabilities
N202-090	Single Amphibious Integrated Precision Augmented Reality Navigation (SAIPAN) System
N202-091	Artificial Intelligence for Anti-Submarine Warfare Training
N202-092	Small Space, Weight, and Power (SWaP) Multilevel Security Cross-Domain Solution
N202-093	Physical Measurement of Corrosion and Wear Damage on Splined Surfaces
N202-094	Novel Multi-Physics Based Simulation Tool for Rapid Heat Damage Assessment of Polymer Composite Aircraft Structures Resulting from Excessive Heat Exposure
N202-095	Next Generation Radar and Electronic Warfare Processing Technology
N202-096	Rotorcraft Crash Sensor for Active Safety Systems and Mishap Dynamics Recording
N202-097	Innovative Aerial Refueling Hose Stowage Methods
N202-098	Voice Recognition to Support Assessment of Cross Platform Situational Awareness and Decision Making
N202-099	Implementing Neural Network Algorithms on Neuromorphic Processors
N202-100	Preload Indicating Hardware for Bolted Joints
N202-101	Data Link Bottleneck Reduction Using Big Data Analytics
N202-102	Low Cost High Performance A Size Sonobuoy Power Amplifier
N202-103	Software Toolset for Rapid Finite Element (FE) Mesh Generation of As-Built Large Laminated Composite Structural Components
N202-104	Time and Phase Synchronization of Radio Frequency (RF) Sources across Multiple Unmanned Aerial System/Vehicle (UAS/UAV) Platforms
N202-105	Digital Twin Technologies to Improve Mission Readiness and Sustainment
N202-106	Alternative Software Architecture for Personal Electronic Maintenance Aids
N202-107	Radio Communication with Hypersonic Aerial Vehicle
N202-108	Modeling Neuromorphic and Advanced Computing Architectures
N202-109	Launch System for Group 3-5 Unmanned Aerial Vehicles for Land- and Sea-Based Operations
N202-110	Miniature 360-degree Multispectral/Hyperspectral Staring Imaging System

N202-111 Desktop Tactics Trainer for Maritime Patrol Aircraft

N202-112 Multi-Domain Data Fusion Instructional Strategies and Methods for Pilot Training

N202-113 Mid-Body Range Safety Subsystem

N202-114 High Fidelity Electromagnetic Design, Prediction and Optimization of Airborne Radomes

N202-115 Monolithic Dual-Band Quantum Cascade Laser

~~N202-116~~ [Navy has removed topic N202-116 from the 20.2 SBIR BAA]

N202-117 Optimized Subtractive Manufacturing - Right Parts, Right Time, Every Time

N202-118 Passive System for Detection and Identification of UAVs Using Multispectral/Hyperspectral Imaging Technologies

N202-119 Cross Deck Pendant Health Monitoring

N202-120 Improved and More Robust Automatic Target Classifiers

N202-121 Identifying and Characterizing Cognitive Sensor Systems in Tactical Environments

N202-122 Innovative Multi-Physics-based Tool to Minimize Residual Stress / Distortion in Large Aerospace Aluminum Forging Parts

N202-123 Generation of Hydrogen from Seawater, Powered by Solar PV, Leading to Cogeneration of Electricity and Potable Water

N202-124 Thermal and Magnetic Packaging for Large Superconducting Systems

N202-125 Broadband Photoconductive Terahertz Focal Plane Arrays

N202-126 Scenario Development and Enhancement for Military Exercises

N202-127 Electrical Energy Sensing Device for EOD Detection, Location and Diagnosis of Electronic Safe & Armed Fuzes

N202-128 Innovative Approaches in Design and Fabrication of 3D Braided Ceramic Matrix Composites (CMC) Fasteners

N202-129 Nosetip Ablation Sensor and Telemetry Interface Unit for Hypersonic Vehicle Thermal Protection Systems

N202-130 Cold-water Diving Wetsuit

N202-131 Intelligent Laser System for CBM+ of Naval Platforms

N202-132 Novel Methods to Mitigate Heat Exchanger Fouling

N202-133 Multimodal Interaction Technologies to Support Small Unit Leaders

N202-134 Radio Frequency Buoyant Cable Antenna Transfer Mechanism

N202-135 Model Based Systems Engineering for Tactical Data Link Systems

~~N202-136~~ [Navy has removed topic N202-136 from the 20.2 SBIR BAA]

N202-137 Sensor Embedding Procedures in Candidate Hypersonic Material Specimens

~~N202-138~~ [Navy has removed topic N202-138 from the 20.2 SBIR BAA]
N202-139 Probability of Kill Modeling for Hypersonic Vehicle Missions
~~N202-140~~ [Navy has removed topic N202-140 from the 20.2 SBIR BAA]
N202-141 Investigate the use of Discrete Patterned Roughness for Turbulent Transition Control in a Hypersonic Boundary Layer
~~N202-142~~ [Navy has removed topic N202-142 from the 20.2 SBIR BAA]
N202-143 Plasma Switches and Antennas for Contested Electromagnetic Environments
N202-144 Predictive Physics-Based Model for Projectile Trajectory Instability
N202-145 Hypersonic Wake Detection with High Enthalpy Capabilities
~~N202-146~~ [Navy has removed topic N202-146 from the 20.2 SBIR BAA]
~~N202-147~~ [Navy has removed topic N202-147 from the 20.2 SBIR BAA]

N202-088

TITLE: Advanced Low-Level Parachute System

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

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Develop a low-level parachute system to insert forces while allowing the aircraft to fly faster and lower than current systems.

DESCRIPTION: Current military low-level parachute systems take one of two paths. Non-maneuverable systems allow for many parachutists in the air or maneuverable systems with limited glide capabilities. Current systems were designed to operate in a mountainous environment and do not emphasize a lower operational altitude. The current systems utilize a front mounted reserve that interferes with the wearing of combat equipment. Current building, antenna, span, and earth (BASE) parachute systems are regularly used at altitudes of less than 500 ft. above ground level (AGL) with initial velocities, both horizontal and vertical, of zero. Advances in the use of lightweight fabric and innovative sewing methods allow BASE parachute systems to minimize system weight.

An Advanced Low-Level (ALL) parachute system could combine the innovations of the commercial BASE parachute systems, paraglider reserves, and possibly static line military systems. The design needs to provide a consistent on-heading opening while dissipating the energy from the exit speed and allowing for glide to a small drop zone. The challenges of speed, weight, and altitude pose the greatest risk to a successful design.

Developing an ALL parachute system could replace the current low-level parachute system. The ALL parachute system could require a different sized system to meet the weight and range requirement. The ALL parachute system must include reliability and safety systems for personnel operations. Proposed systems should meet the following performance specifications:

Minimum exit altitude: Threshold (T) 750 ft. AGL Objective (O) 500 ft. AGL

Dropzone height: (T) 2,000 feet Mean Sea Level (MSL) Objective (O) 4,500 ft. MSL

Weight capacity not including ALL system: (T) 105-300 lbs. (O) 105-330 lbs.

Aircraft exit speed: (T) 145 knot indicated air speed (KIAS) (O) 150 KIAS

Dropzone size: (T) 360m X 270m (O) 240m X 180m

PHASE I: Develop concepts for an ALL parachute system meeting the requirements described above. Demonstrate the feasibility of the concepts in meeting Marine Corps needs and establish the concepts for development into a useful product for the Marine Corps. Use material testing and analytical modeling to establish feasibility, as appropriate. Provide a Phase II development plan with performance goals and key technical milestones and that addresses technical risk reduction.

PHASE II: Develop a prototype for evaluation to determine its capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for the ALL parachute 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 an initial design that will meet 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. Determine its effectiveness in an operationally relevant environment. Support the Marine Corps in test and validation to certify and qualify the system for Marine Corps use.

Low level parachutes are currently used primarily as recreational in the United States. New parachute systems could be used by airborne firefighting services to increase reliability and improve access to remote fires. New designs could be utilized by companies interested in delivering items in Class G airspace.

REFERENCES:

1. Mohammadi, Mohammad A. & Johari, Hamid. "Computation of Flow over a High-Performance Parafoil Canopy." *Journal of Aircraft*, 47, 2010, pp. 1338-1345. doi:10.2514/1.47363. <https://arc.aiaa.org/doi/abs/10.2514/1.47363>
2. Eslambolchi, Ali & Johari, Hamid. "Simulation of Flowfield Around a Ram-Air Personnel Parachute Canopy." *Journal of Aircraft*, 50, 2013. doi: 10.2514/6.2013-1281. <https://arc.aiaa.org/doi/abs/10.2514/1.C032169>
3. Soreide, Kjetil, Ellingsen, Christian Lycke and Vibeke Knutson. "How Dangerous Is BASE Jumping? An Analysis of Adverse Events in 20,850 Jumps From the Kjerag Massif, Norway." *The Journal of Trauma: Injury, Infection, and Critical Care* 62, no. 5, May 2007, pp. 1113–1117. doi:10.1097/01.ta.0000239815.73858.88. <https://www.ncbi.nlm.nih.gov/pubmed/17495709>

KEYWORDS: Parachute, Static Line, BASE, Canopy, Lightweight Fabric, Sewing

N202-089

TITLE: Focused Enhanced Acoustic-Driver Technologies (FEAT) for Long Range Non-Lethal Hail and Warn Capabilities

RT&L FOCUS AREA(S): Directed Energy, Microelectronics

TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Develop a Focused Enhanced Acoustic-Driver Technology (FEAT) for Long Range Non-Lethal hail and warn capabilities. Provide long range non-lethal hail and warn capabilities to deny access into/out of an area to individuals, move individuals through an area, suppress individuals in open and confined spaces, and stop vehicles and vessels by providing intelligible voice commands to vehicle/vessel operators.

DESCRIPTION: Typical Commercial Off-the-Shelf (COTS) acoustic hailing devices (AHDs) employ an array of acoustic drivers in their systems that produce peak acoustic outputs (Sensitivity – anechoic) of ~ 109 dB. These acoustic arrays also employ acoustic beamforming techniques using 8 or more single acoustic drivers to produce maximum peak sound pressure levels (SPLs) at 1 meter in excess of 156 dB (A-weighted). To meet current DoD Hail and Warn range performance requirements, these COTS AHD (arrayed) systems get very large (e.g., > 64 inches in diameter) and very heavy (e.g., > 350 pounds), and are expensive (e.g., > \$100K) [Refs 1-2]. Improving the range and voice intelligibility performance of these hail and warn devices is dependent on 4 primary AHD system performance specifications: (1) increasing the acoustic output levels of each of the acoustic drivers (measured in SPLs); (2) increasing the gain in delivered SPLs achieved by employing adaptive beamforming techniques [Ref 3]; (3) improving the clarity/intelligibility and sound penetration capabilities of the voice/warning signal commands delivered at range through complicated battlefield atmospheres by using lower frequencies (e.g., projecting audible frequencies (in-air) from ~ 100 – 2500 Hz) [Ref 4]; and (4) implementing an atmospheric compensation algorithm that will allow for better targeting of individuals at distance in typical battlefield atmospheres.

Increasing the acoustic output levels of the acoustic drivers from 109 dB to 123 dB or greater is a technical challenge. This 14 dB increase in sound pressure level (SPL) equates to a 14X increase in AHD loudness as this is a logarithmic scale. This increase will require research to develop stronger magnets but with lower mass and stronger diaphragm materials to increase overall system reliability. The resulting full-system acoustic driver, which includes the magnet, compression driver and direction horn, shall weigh less than 3 pounds. The AHD shall also incorporate an adaptive beam forming algorithm that will increase the maximum peak sound pressure level output of the entire system. Maximum SPLs in excess of 156 dB (A-weighted) shall be achieved. Improved voice intelligibility shall be achieved at ranges in excess of 2000 meters by employing focused low frequency sound (projecting sound in the 100 – 2500 Hz frequencies ranges). These low frequencies propagate better near the ground and just above the air/water surface, and also penetrate better into structures and confined spaces such as vehicles and/or buildings. Finally, this next-generation AHD system shall incorporate an atmospheric propagation correction tool to allow for better target aiming at range, i.e., the tool will correct for normal acoustic beam refractions in the atmosphere and for windage.

The newly developed next generation compact/lightweight AHD will achieve long range hail and warn at ranges in excess of 2000 meters. The next-gen AHD will incorporate enhanced acoustic drivers (with single acoustic driver outputs of > 123 dB), an acoustic beam forming algorithm, projection of lower frequencies (100 -2500 Hz) for improved voice command intelligibility, and an atmospheric compensator tool to allow for better more precise aiming.

PHASE I: Develop concepts for an improved (more compact/lightweight and longer range) acoustic hailing device (AHD) that meets the requirements described above. This includes developing (1) an

improved (123 dB) acoustic output driver design, (2) an optimum adaptive beamforming algorithm for this AHD, (3) low frequency sound projection for improved voice command intelligibility at long ranges, and (4) an atmospheric compensator tool incorporated into the AHD for better targeting. Demonstrate the feasibility of each of these four key AHD subsystems in meeting JNLWD/Marine Corps needs through material testing and analytical modeling, as appropriate of each of the four key sub-systems, as well as for the resulting improved AHD system. Establish that the concepts can be developed into a useful product for the Joint Services. Provide a Phase II development plan with performance goals and key technical milestones, and that will address technical risk reduction.

PHASE II: Develop a next-generation AHD prototype for evaluation to determine its capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for the next generation AHD. Prototype and test all four key subsystems of the new AHD. Evaluate the system performance of each of the 4 key subsystems and the next-gen AHD system prototype. Confirm and modify the modeling and the 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 JNLWD/Marine Corps hail and warn requirements. Prepare a Phase III development plan to transition the technology to Joint Service use.

PHASE III DUAL USE APPLICATIONS: Support the JNLWD/Marine Corps in transitioning the technology for Joint Service use. Develop the next-generation Acoustic Hailing Device for evaluation to determine its effectiveness in an operationally relevant environment. Support the JNLWD/Marine Corps for test and validation to certify and qualify the system for Joint Service use.

A compact, lightweight, long-range acoustic hail and warn capability has significant commercial applications beyond the DoD. Other government agencies, such as the Department of Justice (DoJ) and the Department of Homeland Security (DHS) to include Customs and Border Patrol have actively been researching these types of AHDs to again deliver voice command warnings at ranges in excess of 2000 meters. Local civilian law enforcement specifically conducts missions to support both building entry, clear-a-space, and orderly evacuation. 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 cost all while drastically improving AHD performance.

REFERENCES:

1. "LRAD 1000RX Remotely Operated, Integrated Communication Systems Datasheet." Long Range Acoustic Device (LRAD) Corporation, San Diego, CA. https://adsinc.com/wp-content/uploads/2018/06/LRAD_Datasheet_1000RX.pdf
2. Scott, Richard J. (Joint Non-Lethal Weapons Directorate) and Eggert, Joseph (Naval Surface Warfare Center Dahlgren), Distributed Sound and Light Array (DSLAs) Lite - Balikatan Experiment 5 MAY 2014, Quantico, VA, 5 May 2014. navysbir.com/n20_2/N202-089-REFERENCE-2-DSLAs_Lite.pdf
3. Wikipedia, Adaptive beamformer, , 10 May 2019 https://en.wikipedia.org/wiki/Adaptive_beamformer
4. Brixen, Eddy B., "Facts About Speech Intelligibility." DPA Microphones Inc. <https://www.dpamicrophones.com/mic-university/facts-about-speech-intelligibility>.

KEYWORDS: Acoustic Hailing Device, AHD, Acoustic Drivers, Compression Drivers, Acoustic Adaptive Beamforming, Voice Intelligibility, Acoustic Atmospheric Compensator Tool

N202-090

TITLE: Single Amphibious Integrated Precision Augmented Reality Navigation (SAIPAN) System

RT&L FOCUS AREA(S): Autonomy, Artificial Intelligence/ Machine Learning

TECHNOLOGY AREA(S): Ground Sea

OBJECTIVE: Develop a single amphibious integrated precision augmented-reality navigation system (SAIPAN) that would integrate the GPS signals from the vehicle/craft's receiver with inertial guidance data and manually entered coordinates to display virtually marked lanes that an operator would use to assist in maneuvering. Ensure that the integrated system is able to communicate with other systems in the littoral environment to create a shared common operating picture, e.g., vehicles could receive updated information on explosive and non-explosive obstacles in the battle space and virtually display these obstacles onto an operator's display that would enable the vehicle/craft operator to maneuver with much higher precision within smaller lanes. Design a system that would have a mounted hardware suite for vehicles/crafts (e.g., Amphibious Combat Vehicle (ACV), Assault Breacher Vehicle (ABV), Amphibious Assault Vehicle (AAV), Landing Craft Air Cushion (LCAC), Landing Craft Utility (LCU)) and a portable/handheld hardware suite for small boats/personal watercraft (Combat Rubber Raiding Craft (CRRC)/RECON Team/SEAL Team).

DESCRIPTION: An integrated driver/operator display that uses a precision navigation and timing system to generate virtually marked lanes is needed for the littoral combat force of the 21st century. The Naval force lacks the ability to mark assault lanes in the littorals from the deep water through the beach zone using a single integrated system. Different platforms use different methods from the physical marking of lanes by humans through the virtual marking of lanes using GPS coordinates. Both the Navy and Marine Corps use different precision navigation systems on land and in the water. The Navy's Amphibious Breaching System (ABS) contains four systems: (1) Coastal Battlefield Reconnaissance Asset (COBRA), (2) MINENet Tactical, (3) JDAM Assault Breaching System (JABS), and (4) Augmented Reality Visualization for the Common Operating Picture (ARVCOP). The ARVCOP program was a USMC program within the ABS but failed and was not fielded. Without this capability the Naval Force cannot mark cleared lanes within mined waters and land. This increases risks to craft operating within a mined littoral environment. The Naval force must currently either accept the risk or spend large amounts of time, resources, and personnel to clear larger areas of land and sea mines. The Naval force could reduce risk and costs by investing in a single integrated add-on augmented/virtual driver display that provides a precision navigation capability.

This single integrated add-on augmented/virtual driver display would pull GPS information from existing and future precision navigation suites (e.g., DoD Assisted GPS Receiver (DAGR), MAPS) and combine it with manually entered information to generate an augmented reality display. The operator would manually enter the grid points of cleared lanes into the system prior to departing the ship. The SAIPAN would combine this information with precision navigation and timing information of existing programs to build the augmented reality picture on the driver display. Once the craft departs the amphibious ship, the operator would drive the craft via the display. The virtual lanes on the display would enable the craft to operate in much narrower lanes with greater confidence than with current naval Tactics Techniques and Procedures (TTPs). The SAIPAN would have a mounted capability for larger crafts/vehicles (e.g., LCAC/LCU/Rigid Hulled Inflatable Boat (RHIB)/ACV/Light Armored Reconnaissance Vehicle (LAV)) and dismounted capability for smaller crafts/vehicles (e.g., Combat Rubber Raiding Craft, Bridge Erection Boat, Divers, Special Forces) and people. Future increments of SAIPAN would take real-time information provided by both sensors and humans and integrate it with existing libraries of information to provide a real-time common operational picture. Inertial navigation data may also be integrated. The precision navigation display would show individual explosive and non-explosive obstacles and allow the

craft to maneuver around these obstacles vice having to remove them, increasing the littoral mobility of craft and decreasing the amount of time and resources to clear this area of obstacles.

There are some government off-the-shelf augmented reality driver displays that meet some of the specification listed below.

The key performance parameters of the SAIPAN System include the following:

- Error rate of <1m
- Capable of integrating precision navigation and timing from COTS/GOTS GPS receiver
- Capable of integrating manually typed/downloaded navigation points from vehicle/craft operator
- Driver display video must be of a quality that meets or exceeds current craft/vehicle systems
- Driver display must enable the operation of the vehicle at night and day
- Augmented reality must be able to be seen at night within the driver/operator compartment
- Augmented reality must show left and right lateral limits of lanes
- Display must include 360 degree “birds eye-view” so operator can see direction of vehicle within the lane
- System must be compatible with electric power input from military craft/vehicle. Or it should be capable of operating from rechargeable batteries rated for the austere environments, per MIL-STD 810
- Vehicle-mounted system: Physical characteristics that permit installation in amphibious craft, minimizing cube and weight
- Portable/hand-held system: Physical characteristics equivalent to Commercial Off-the-Shelf tablets or smart phones (e.g., Panasonic Toughpad, Blackview BV5500)

PHASE I: Develop concepts for a SAIPAN system 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 for the Marine Corps. Establish feasibility by material testing and analytical modeling, as appropriate. Provide a Phase II development plan with performance goals and key technical milestones, and that will address technical risk reduction.

PHASE II: Develop a scaled prototype for evaluation to determine its capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for the SAIPAN 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 an initial design that will meet 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 a SAIPAN system for evaluation to determine its effectiveness in an operationally relevant environment. Support the Marine Corps for test and validation to certify and qualify the system for Marine Corps use.

The system has the potential to be employed by large ships and small crafts to navigate during inclement weather and thus improve safety.

REFERENCES:

1. Zysk, Thomas, et al. “Augmented Reality for Precision Navigation: Enhancing Performance in High-Stress Environments.” GPS World, 5 August 2019.
<https://www.gpsworld.com/defensenavigationaugmented-reality-precision-navigation-13032/>

2. Faturechi, Robert, et al. "Iran has Hundreds of Naval Mines, U.S. Navy Minesweepers Find Old Dishwashers and Car Parts." ProPublica, 5 August 2019. <https://www.propublica.org/article/iran-has-hundreds-of-naval-mines-us-navy-minesweepers-find-old-dishwashers-car-parts>

3. Example of User Display Images for ARVCOP, SSN-8 and TIMEZERO. https://navysbir.com/n20_2/N202-090-REFERENCE-3-SAIPAN-Images.pdf

KEYWORDS: Augmented Reality, Precision Navigation, Driver Display, Navigation, Precision, Virtual

N202-091

TITLE: Artificial Intelligence for Anti-Submarine Warfare Training

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platform, Information Systems, 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: Augment the Navy Anti-Submarine Warfare (ASW) capability via the addition of an artificial intelligence (AI) training aid that can also assist as an operational decision-support tool.

DESCRIPTION: Artificial Intelligence (AI) has increased dramatically over the last five years. This SBIR topic seeks a phased approach to implementing a tactical and evolving Anti-Submarine Warfare (ASW) application with AI technology, specifically the application of AI technology to passive ASW analysis. AI augmentation should be aggressively pursued to increase the manning and training aspects of the AO (operational availability) equation across the Navy.

This topic is not a case for replacing an acoustic operator with a machine, but rather should be seen as an attempt to point out why AI assistant technology during training and operations would be beneficial not just to the operator, but to the overall ability of the U.S. Navy to conduct ASW operations. The importance of the human operator's ability to adapt to new information, answer questions about information, and truly analyze an ASW target's characteristics and behavior cannot be overstated. The human acoustic operator is responsible for providing target-quality data, under any conditions and in any circumstance, to complete the kill chain. That job is not one that machines can currently perform unaided by a human, but is one that machines can augment effectively. Although the AI assistance can provide analytical tools on top of the data, the human operator will still be the one to review the outputs of the algorithms and question whether it makes sense or not.

Acoustic operators go through approximately two years of initial training, and 18-24 months of advanced, hands-on training at the squadron, to become a basic qualified "operator." In order to become proficient, or even experienced, the operator needs years of additional submarine contact time. In order to build proficiency, the operator spends long hours on deployment or detachments, conducting ASW on adversary submarines and observing the differences between his or her training and the data that he or she gains while on-station. With additional capabilities of the Maritime Patrol community coming online, the demands on a given acoustic operator have only increased.

With these increased demands, we must recognize the limitations of human acoustic operators when analyzing acoustic data, especially before initially locating a subsurface target, when unsure of when and where contact will appear. As human beings, they can only apply their cognitive process to information from a single sonobuoy at a time. Experience and training may allow the operator to process the information faster and more accurately, but no matter how quickly they work through the information they can only process a limited number of sonobuoys at one time. Additionally, human operators must choose to allocate their cognitive effort into three categories: speed, accuracy, and quantity. At any given time, an operator may choose to allocate their effort to two of the three categories. If an operator desires

to analyze a large quantity of data with a high degree of accuracy, they will sacrifice speed. If they wish to analyze the same set of data quickly, they will sacrifice accuracy. If instead they desire to analyze data with a high degree of accuracy and a high measure of speed, they must reduce the quantity of data they analyze. Although there are exceptions with expert acoustic operators, the majority of acoustic warfare operators (AWOs) are limited by these constraints.

Fortunately, AI that is trained on representative data sets can assist AWOs in the training and operational context. Initially, an AI assistant could provide novice AWOs with explanations and reasoning why it notices a contact within a set of acoustic data. Additionally, confidence values with those explanations would further involve the human trainee in the situation. Flag officers have recently requested that information that AI systems output should come with a confidence factor as standard practice. Although the trainee would have the final say in all matters, the AI can help scaffold the training so that the trainee has useful information about multiple different variables, and the reasoning why confidence values are what they are. For example, given a training scenario in a body of water, the AI could inform the trainee that there is a 60% match based on acoustic signature and that it is an “X” class submarine. It must also inform that overall confidence value is only 40% because it is rare that the “X” class submarine is ever in this particular body of water. This “pulling back of the curtain” via traceable and explainable AI can ensure the student is privy to more of the information and situation than a human could experience unassisted. This will also assist in deterring adversarial AI practices that can confuse and trick AI systems into believing something that is not true. If successful during training, this AI capability could also be used in operational settings and updated, via modifying its own code as it learns, in real-time to ensure AWOs conducting operations have all the relevant information. This would allow the assistant to improve the ability of crews to do ASW on station as it mitigates a limitation of human operators. Where a human must choose between speed, accuracy, and quantity, an AI need not make such a choice. When “plugged-in” to the aircraft’s ASW data stream, an AI with sufficient processing power is able to analyze all ASW data in real-time with accuracy (within the parameters of its training). Although the topic is primarily focused on the training aspect, successful implementation of the technology certainly has use beyond training to help all Maritime Patrol aircrew become more effective at their primary role of ASW.

The final solution must meet AI ethics principles outlined by the Department of Defense (Responsible, Equitable, Traceable, Reliable, Governable) [Ref 7] and will meet Risk Management Framework, Cyber and Navy Marine Corp Internet (NMCI) guidance [Ref 6].

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. 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: Design, develop, and demonstrate feasibility of AI techniques, methods, and models, and determine the optimum approach for this topic. Demonstrate the feasibility of the proposed training capability within an undersea (or relevant) domain with publicly available training data. The early system should demonstrate a form of explainability and confidence values in outputs provided. Outline future concepts for the inclusion of self-tuning algorithm parameters. AI ethics principles outlined by the Department of Defense will be adhered to (Responsible, Equitable, Traceable, Reliable, Governable). The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and prototype the proposed solution to integrate into a Navy ASW sample training environment. The prototype capability should ingest real-world training data. Demonstration of the prototype AI assistant, that has been trained with real-world data, providing explainable AI recommendations with confidence values to novice AWOs conducting training using low to medium fidelity training devices or simulators. Considerations of how the standalone training device may use continuous data from an operating environment to refine the algorithm's parameters should be included in a Phase II demonstration. Continued adherence to AI ethics principles outlined by the Department of Defense will be required (Responsible, Equitable, Traceable, Reliable, Governable). Work in Phase II may become classified. Please see note in the Description section.

PHASE III DUAL USE APPLICATIONS: Refine the capability from the Phase II final demonstration and show consistent reliability in a known performance envelop. A Phase III capability must include and demonstrate a function to self-tune its own algorithm based on new data inputs. Integrate within current acoustic warfare operator training and go through verification and validation testing, as well as effectiveness and usability testing. Continue to adhere to AI ethics principles outlined by the Department of Defense (Responsible, Equitable, Traceable, Reliable, Governable). Contractors will harden the software architecture and implement Risk Management Framework guidelines to support IA compliance, including requirements to allow installation on SIPRNet or Navy Internet Protocol Networks (NIPRNet) if appropriate for transition path. The final capability will be required to exist in a representative training environment with all information assurance and cyber security requirement approvals. Final steps will investigate the level of effort required to convert the AI assistant to an operational assistant in the field. Developing AI decision-support tools is beneficial for a wide variety of domains and commercial industries. Techniques and procedures used to develop acoustic training may be immediately of use to other domains, such as oceanography and survey research organizations that study the world's oceans and other bodies of water. Additionally, the technical approaches may be applicable to industries outside of pure acoustics, as the AI techniques that will be implemented will cater to somewhat fuzzy training data sets that may or may not be flush with data samples. As the topic may involve image recognition, as well as acoustic recognition algorithms, the results could also be applicable to areas involving surveillance and automatic image classification.

REFERENCES:

1. Russell, S. J. & Norvig, P. "Artificial Intelligence: A Modern Approach." Pearson Education Limited, 2016. <https://www.amazon.com/Artificial-Intelligence-Modern-Approach-3rd/dp/0136042597>
2. Duda, R. O., Hart, P. E. & Stork, D. G. "Pattern classification." John Wiley & Sons, November 9, 2012. https://books.google.com/books/about/Pattern_Classification.html?id=Br33IRC3PkQC
3. Goodfellow, I., Bengio, Y. & Courville, A. "Deep learning." MIT Press, 2016. <https://mitpress.mit.edu/books/deep-learning>
4. National Science & Technology Council, Artificial Intelligence Research & Development Interagency Working Group, Subcommittee on Networking & Information Technology Research & Development, Subcommittee on Machine Learning & Artificial Intelligence, and the Select Committee on Artificial Intelligence of the National Science & Technology Council. "2016-2019 Progress Report: Advancing Artificial Intelligence R&D." <https://www.nitrd.gov/pubs/AI-Research-and-Development-Progress-Report-2016-2019.pdf>
5. Select Committee on Artificial Intelligence of the National Science & Technology Council. "The National Artificial Intelligence Research and Development Strategic Plan: 2019 Update." <https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf>

6. “Risk Management Framework (RMF) Overview: [https://csrc.nist.gov/projects/risk-management/risk-management-framework-\(RMF\)-Overview](https://csrc.nist.gov/projects/risk-management/risk-management-framework-(RMF)-Overview)

7. “AI Principles: Recommendations on the Ethical Use of Artificial Intelligence by the Department of Defense.” Defense Innovation Board. https://media.defense.noclick.gov/2019/Oct/31/2002204458/-1/-1/0/DIB_AI_PRINCIPLES_PRIMARY_DOCUMENT.PDF

KEYWORDS: AI, Artificial Intelligence, Anti-Submarine Warfare, ASW, Machine Learning, Decision-Support, Explainability

N202-092 TITLE: Small Space, Weight, and Power (SWaP) Multilevel Security Cross-Domain Solution

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

TECHNOLOGY AREA(S): Air Platform, Information Systems, Battlespace

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 form factor, integrated, multi-level security, cross-domain solution.

DESCRIPTION: The Navy's integrated warfighting strategy, driven by advancing adversaries, calls for high levels of interoperability while at the same time maintaining the highest level of cybersecurity protection. Multiple security enclaves within a platform are becoming commonplace across the Navy, but no common solution exists. Along with coordination of systems and sensors within a platform, datalinks between similar and dissimilar aircraft are critical to success for the future of the Navy. Due to the current security posture across the Department of Defense (DoD), data of different security levels are often unable to be integrated, limiting warfighters' ability to make tactical decisions. The development and fielding of a small form factor, integrated, multi-level security, cross-domain solution able to be tailored to a platform's need while maintaining a set of common standards would save each program from redundant development [Refs 1, 2]. Each Naval program will have their independent needs for number of domains, required classification levels, and SWaP constraints, but at a minimum, the developed technology must meet the following requirements:

- Demonstrate concurrent operation across four distinct security domains.
- Operator interface with access to all security levels.
- Develop rulesets to control data flows within, in, and out of the system.
- Send and receive data across each domain while ensuring no spillage to unapproved domains with Government designated simulation environment.
- In-flight demonstration of technology with similar and dissimilar aircraft in Government-designated scenario.
- Process DoD classified data at all levels of classification.
- Plan for National Security Agency (NSA) approval as a cryptologic device [Refs 3, 4].
- Maximum physical size of 1" x 4" x 6" per security domain.
- Maximum weight of 8 ounces per security domain.
- Operate via aircraft power at 28VDC or 400Hz AC.
- MIL-STD 810H [Ref 5] for environmental effects.

Without a common solution and coordination of system architecture design, the Navy is at risk of stove piped solutions that would require complete redesign when asked to fight together.

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. 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: Design and demonstrate feasibility of a flyable routing solution scalable to various platform configurations with a cross-domain solution addressing multiple security levels. Develop a draft architecture and plan for attaining NSA approval for cryptologic systems. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Further design and develop the solution identified in Phase I into a prototype. In conjunction with the Government, develop simulated data and then use that data to demonstrate the prototype. Develop an unclassified set of controls to handle organic and off-board classified data types provided by the Government. Initiate process of attaining NSA approval for designed hardware and software. Work in Phase II may become classified. Please see note in the Description section.

PHASE III DUAL USE APPLICATIONS: Complete development of the cross-domain control measures and perform final testing in a Government-designated simulation environment. After identifying specific data types and classifications of airborne system data, demonstrate a fully capable multi-level security cross-domain solution in a live fly event. Continue work with the Government sponsor to gain NSA approval for provided approach and transition to applications across Naval airborne platforms.

The control measures and techniques employed may benefit companies seeking to protect proprietary data while working with other organizations. This technology will apply beyond the contractors supporting the DoD. Medical, financial, and civilian electronics industries will benefit from a technology that allows networking with competitors for collaboration while preventing proprietary or personal data from spillage onto an improper domain.

REFERENCES:

1. Koelsch, Col. B. F. "Solving the Cross Domain Conundrum." US Army War College, Strategy Research Project 2013.
<https://pdfs.semanticscholar.org/26b3/0eab984c8c5c31e9a18e75b4ac4c52b1c14c.pdf>
2. US Joint Staff. "Cross-Domain Synergy in Joint Operations, Planners Guide, January 2016."
https://www.jcs.mil/Portals/36/Documents/Doctrine/concepts/cross_domain_planning_guide.pdf?ver=2017-12-28-161956-230
3. National Security Agency/ Central Security Service. "Information Assurance Capabilities, Data at Rest Capability Package, Version 4.0. January 2018."
<https://www.nsa.gov/Portals/70/documents/resources/everyone/csfc/capability-packages/dar-cp.pdf>
4. National Security Agency/ Central Security Service. "Information Assurance Capabilities, Commercial Solutions for Classified, Harnessing the Power of Commercial Industry,,September 2018.
<https://www.nsa.gov/Portals/70/documents/resources/everyone/csfc/csfc-faqs.pdf>
5. 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: Multi-level Security, Cross-domain Solution, Data Sorting, Adaptive, Small Form-factor, Modular

N202-093

TITLE: Physical Measurement of Corrosion and Wear Damage on Splined Surfaces

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

TECHNOLOGY AREA(S): Air Platform, Materials

OBJECTIVE: Develop an innovative measurement system capable of quantifying depth of corrosion and wear damage on rotor mast splines (located on the gearbox output driveshaft) to quantify the depth of damage present prior to repair effort to justify repair decision and quantify the depth of material removal during repair/final surface profile to support the justification of the mast's continued use.

DESCRIPTION: There is currently a need for a measurement device to identify the extent of, and depth of, corrosion present in and around mast splines. Surface corrosion and pitting damage on the V-22 Proprotor Gearbox (PRGB) mast splines result in removal of the PRGB from the aircraft. The mast has three splined areas external to the PRGB. Current damage tolerances of 0.0005 inches allow for minimal material removal in the splined areas of the mast. Current measurement tooling is limited to C-micrometer for mast diameter dimension-over-pins measurement and a ball scribe/surface defect probe for determining depth of damage on mast splines. The geometry of the mast splines precludes use of other standard measurement processes (i.e., depth micrometers). Initial damage inspection does not currently measure accurately the depth of damage. After damage is removed dimension of pins is used to confirm that enough material remains on the mast. If measurement is below allowable limits, the PRGB is removed resulting in replacement and repair cost of approximately \$8.5K including travel costs.

Two types of measurements are necessary to evaluate and repair mast spline damage. First, existing corrosion/wear damage must be quantified to determine feasibility of repair within damage limits. Second, the material condition of mast (surface profile) after repair must be measured to ensure the repair did not exceed limits. The proposed system must allow for damage depth measurement with a tolerance of 0.0005 inches while mast is installed in the PRGB on the aircraft wing.

The mast material, Cadmium Plated, per SAE AMS-QQ-P-416 [Ref 3], Type II, Class 2, is 4340 stainless steel. The spline geometry can be found in ANSI B92.1-1996 [Ref 1]. The mast has three splined surfaces, two of which have the same geometry. Spline A (upper mast spline) is an external involute, fillet root, side fit spline with 56 teeth, a pitch of 10/20 and pressure angle of 30 degrees. Splines B and C (center mast splines) are also external involute, fillet root, side fit splines with 104 spline teeth, a 16/32 pitch and pressure angle of 30 degrees.

PHASE I: Design, develop, and perform a concept demonstration of a technology that can determine damage depth on spline tooth-face representative of mast geometry for all three splined areas of mast. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Further develop and demonstrate a prototype of the technology under operational conditions. Verify and validate measurement of spline damage, both pre- and post-repair, on a mast-installed on-wing.

PHASE III DUAL USE APPLICATIONS: Perform final testing and integrate the developed technology into platform Planned Maintenance Interval (PMI) lines. Document the appropriate level of maintenance (organizational or intermediate) depending on the complexity of the system.

This technology could be useful for all other vertical lift application with mast corrosion issues. Successful development could have application with commercial variants of the H-1 (Bell 204 and 205) as well as the Leonardo AW609. Additionally, the offshore helicopter industry has constant exposure to corrosive saltwater environments that drive the need for increased inspections.

REFERENCES:

1. "Involute Splines and Inspection (ANSI B92.1-1996)." American National Standards Institute, 1996. https://infostore.saiglobal.com/en-us/Standards/ANSI-B92-1-1996-1018273_SAIG_SAE_SAE_2370136/ (cost is \$97)
2. "Guide for Eddy Current Testing of Electrically Conducting Materials Using Conformable Sensor Arrays (ASTM E2884-13)." American Society for Testing and Materials (ASTM), International, Book of Standards, Vol. 03.03. <https://webstore.ansi.org/Standards/ASTM/ASTME288413>
3. QQ-P-416F, FEDERAL SPECIFICATION: PLATING, CADMIUM (ELECTRODEPOSITED) (01 OCT 1991) [S/S BY SAE-AMS-QQ-P-416] http://everyspec.com/FED_SPECS/Q/qq-p-416f_22867/

KEYWORDS: Transmission Mast, Corrosion, Pitting, Splined Surface, Damage Depth, Surface Profile Measurement

N202-094

TITLE: Novel Multi-Physics Based Simulation Tool for Rapid Heat Damage Assessment of Polymer Composite Aircraft Structures Resulting from Excessive Heat Exposure

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

TECHNOLOGY AREA(S): Air Platform, Materials

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 multi-physics simulation tool able to quickly assess residual structural integrity of thermoset polymer composite aircraft structures subjected to excessive heat.

DESCRIPTION: Naval aircraft in operation face the risk of over-temperature incidents. These include, but are not limited to, fires and high-temperature exhaust gas impingement. Protection of composite aircraft structures from excessive heat is important since thermally damaged composites are vulnerable to compressive failure. While char or discoloration evidence caused by fire or an overheating event may be visible from inspection of structure surfaces, internal thermal damage underneath the fire protection layer or thermal degradation due to long exposures above the designed to continuous operating temperature cannot be detected or structurally assessed by visual inspection alone. Replacement of suspect components is expensive, reduces aircraft availability, and is a known readiness degrader. Continued operation of a thermally damaged composite structure could result in a catastrophic failure. Without knowing the criticality or distribution of the thermally induced degradation, a repair solution cannot be implemented to restore the damaged component to the required load bearing capacity. Existing simulation tools cannot provide a quick solution for the damage assessment of a large-scale structure experiencing an over-temperature incident.

The Navy seeks development of a rapid-heat damage assessment and failure prediction tool to fill the current technology gap and support its mission driven operation. A high-fidelity solution process must be established to generate a rapid prediction tool that can be updated from additional data collected from inspection. Development of a multi-physics model capable of conservative prediction of the structural response for a given temporal and spatial evolution of thermal environment is desired. The thermal analysis of a composite structure exposed to excessive heat is complex because the heat transfer is controlled by many temperature- and rate-dependent processes such as thermal expansion and contraction, pressure rise, chemical decomposition, formation of matrix cracks, voids and delamination. The proposed approach should take into account the following phenomena: heat transfer, phase evolution and property degradation at micro-macro scale, damage progression under thermal-mechanical loading, multiple failure modes interaction, and multi-component structure failure.

A comprehensive multi-physics model shall account for thermo-mechanical and thermo-chemical effects. The model must have the ability to calculate the temperature distribution within the composite when exposed to excessive heat. The model should take into account the effects of heat conduction, thermoset matrix pyrolysis, oxidation of carbon fibers, thermal expansion and diffusion of decomposition gases on the temperature distribution in the system. The model should be able to predict the composite decomposition kinetics as well as the degraded composite structural response. This model should also

take into account the composite interaction with the associated high-temperature environment. The model should also include damage and failure prediction modules. The damage prediction module should allow the developed model to predict the type of damage depending on the temperature and exposure time, while the failure prediction module should estimate the failure behavior with respect to the over-temperature event characteristics. The inclusion of these two modules should allow the model the capacity to predict the overall behavior of composite structures when exposed to excessive heat.

PHASE I: Design and develop an accurate tool for the modeling of the transfer of heat through a composite exposed to excessive heat in residual strength analysis that includes the analysis of composition decomposition and damage. The accuracy of the model is dependent on the input data, and thermal experiments should be carried out during this phase. A proof of concept demonstration should be performed indicating the ability of the model in establishing a mapping relation between temperature and response of a loaded structural component. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Further develop and validate the model developed during Phase I through component/sub-scale testing. After validation, the model should be extended to multi-component laminated structures and sandwich composite structures. Transition feasibility should also be demonstrated during this phase. Acceptable error between predicted versus experiment can be no more than 2-6%.

PHASE III DUAL USE APPLICATIONS: Finalize and perform necessary testing to verify and validate. Transition to end users and commercial industries. Successful technology development would benefit the commercial aerospace industry.

REFERENCES:

1. Tranchard, P., Samyn, F., Duquesne, S., Estebe, B. and Bourbigot, S. "Modelling Behaviour of a Carbon Epoxy Composite Exposed to Fire: Part I—Characterization of Thermophysical Properties." *Materials*, Vol 10, doi: 10.3390/ma10050494, 2017
2. Tranchard, P., Samyn, F., Duquesne, S., Estebe, B., and Bourbigot, S., "Modelling Behaviour of a Carbon Epoxy Composite Exposed to Fire: Part II—Comparison with Experimental Results," *Materials*, Vol 10, doi: 10.3390/ma10050470, 2017
3. Quintiere, J.G., Walters, R. N. and Crowley, S. "Flammability properties of aircraft carbon-fiber structural composite." DOT/FAA/AR-07/57, 2007. <https://www.fire.tc.faa.gov/pdf/07-57.pdf>
4. Nelson, James B. "Determination of Kinetic Parameters of Six Ablation Polymers by Thermogravimetric Analysis." NASA TN D-3919, 1967. <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19670013969.pdf>

KEYWORDS: Composite Fire, Thermal Analysis, Thermo-Mechanical Model And Thermo-Chemical Model, Property Degradation, Post-Fire Damage Assessment, Failure Modes Interaction, Decomposition Kinetics

N202-095

TITLE: Next Generation Radar and Electronic Warfare Processing Technology

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

TECHNOLOGY AREA(S): Information Systems, Battlespace

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 radar and/or electronic warfare (EW) processing technology to include Synthetic Aperture Radar (SAR) and/or Airborne Electronic Attack (AEA) processing systems for coherent pulsed radio frequency (RF) systems to include new generation non-sinusoidal time-frequency RF waveforms such as wavelets.

DESCRIPTION: A need exists for hardware and software SAR and AEA processing solutions to augment or replace existing airborne processing technology at reduced size, weight, and power (SWaP), and waste heat versus the current state-of-the-art. Current generation commercial digital processor technology recently delivered to the U.S. Navy to perform SAR processing is 0.73 Teraflop, or 1 Trillion Floating Point Operations per Second (TFLOPS) per pound (lb.). This includes 2xCPU's/4xGPU's, power supply, cooling system, 256 GB random access memory (RAM), 3.2 TB Serial Advanced Technology Attachment (SATA) disk, motherboard, and interface elements. Development of processing hardware and software system technology may be digital, optical, hybrid optoelectronic, or of neuromorphic computing capability in order to reduce the SWaP, and waste heat versus existing real-time processing solutions.

OBJECTIVE: 3.0 TFLOPS per LB; THRESHOLD: 1.5 TFLOPS per LB.

The transition goal for this system technology is to reduce the SWaP requirements for air platform integration.

In addition to traditional RF waveforms, such as Linear Frequency Modulated (LFM) chirps, Next Generation SAR and AEA processing system technology should include a capability to process non-sinusoidal time-frequency RF signals, or wavelets; or Low Probability of Detection (LPD), Low Probability of Intercept (LPI) waveforms.

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 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: Design, develop, and demonstrate feasibility of hardware and software SAR and AEA processing solutions to meet the requirements outlined in the Description. The Phase I effort will include prototype plans to be developed under Phase II. LINUX OS preferred over Windows OS.

PHASE II: Develop a prototype-processing technology. Demonstrate and test that the prototype works toward reduced SWaP form factors for integration to air platforms. Optimize the system design for SAR processing with Phase History Data (PHD) to perform real-time (R/T) image formation for X through UHF-Band SAR and AEA applications. R/T SAR image formation from raw PHD requires is estimated to be .01 TFLOP per Megapixel image at X-Band and 2 TFLOP per Megapixel at UHF-Band. Work in Phase II may become classified. Please see note in the Description section.

PHASE III DUAL USE APPLICATIONS: Test processing systems within aircraft platforms. Perform early development, test and evaluation flights from non-Navy air platforms to simplify integration and reduce flight hour costs. If resourced, later development, test and evaluation test flights are likely to be conducted from Navy test aircraft, to include new generation of Unmanned Aerial Vehicles (UAVs). Lightweight systems technology has the potential to bring full performance SAR collection and processing capability to small Unmanned Aerial Systems (UAS) for support to commercial industry, local governments, and academia such as all-weather terrain mapping, mineral exploration, land use pattern analysis, change detection, and 3-D urban modeling.

REFERENCES:

1. Adamy, D. "EW 104: Electronic Warfare Against a New Generation of Threats." Artech House: Boston, 2015. <https://us.artechhouse.com/EW-104-Electronic-Warfare-Against-a-New-Generation-of-Threats-P1707.aspx>
2. Jakowatz, C., Wahl, D., Eichel, P., Ghiglia, D. & Thompson, P. "Spotlight-Mode Synthetic Aperture Radar: A Signal Processing Approach." Springer: New York, 1996. <https://www.springer.com/us/book/9780792396772>

KEYWORDS: Synthetic Aperture Radar, SAR, Size, Weight and Power, SWaP, Airborne Electronic Attack, AEA, In-phase and quadrature components, I/Q Processing, Unmanned Aerial Systems, UAS, Unmanned Aerial Vehicle, UAV

N202-096

TITLE: Rotorcraft Crash Sensor for Active Safety Systems and Mishap Dynamics Recording

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

TECHNOLOGY AREA(S): Air Platform, Bio Medical, Human Systems

OBJECTIVE: Develop a system capable of recording crash dynamics and detecting crash events in real-time, enabling the application of advanced, and life-saving, crash protective technologies.

DESCRIPTION: Current crash protective systems on Naval Aviation platforms rely on primarily "passive" safety systems to protect pilots and aircrew in the event of a crash or other mishap, such as hard landings. Current crash protection technologies, such as aircrew tethers, inertia reels, restraint systems, and energy-absorbing seating systems, minimally respond or adapt to an in-progress or impending mishap. The result is technologies optimized for neither specific crash environments, nor operational use. Crash protective systems are designed to protect aircraft occupants during representative crash pulses, and, in some cases, compromises must be made between crash protection and operational usability. If a crash sensor/recording system were employed, safety systems (such as restraint pretensioners, airbag systems, crashworthy seats, or mobile aircrew restraints) could actively respond to an impending or ongoing crash event.

In Naval Aviation, no recordings are made of crash acceleration data from mishap events, outside of infrequent test events. The dynamic environments that crashworthiness and escape system engineers work with are often reconstructed more from subjective assessment than from available data. A number of assumptions create a best-educated guess as to the actual conditions of an event. In many cases, the dynamic environments to which U.S. Navy and Marine Corp aircrew are being exposed during mishaps are not known. Further incremental increases in mishap survivability have been hindered by the void of actual mishap acceleration data in spite of the fact that computerized controllers can sense and respond to a developing acceleration environment related to an aircraft crash or escape event.

The Navy is seeking a crash detection/recording capability to measure accelerations (notionally +/- 1000g) and angular rates (notionally +/- 2,500 deg/sec) at locations of interest distributed throughout the airframe at sample rates (notionally 20,000 samples/second) and quality necessary to reconstruct the highly kinematic environment present during mishaps. In addition, a system/sensor design, methodology, and algorithm to detect and discriminate mishaps from other events in real-time, such that active safety systems can be triggered early enough in the mishap event to improve occupant survivability and prevent inadvertent activation. The advantage of distributing sensors, including accelerometers and/or angular rate sensors, in multiple locations of interest is that accelerations and rotation rates associated with mishap detection may occur at different times throughout the airframe. Depending on crash conditions a system capable of sensing/recording at multiple locations has the potential to detect mishaps sooner than a single crash sensor, enabling timely activation of crash protection systems.

The proposed system to record and detect crashes should be capable of:

- 1) recording crash accelerations and angular rates at distributed locations throughout air frame at a quality sufficient for crash reconstruction (including pre- and post-trigger data),
- 2) discriminating mishaps from operational/landing dynamics in real-time,
- 3) triggering future active safety systems as early as practical during a dynamic event in order to enable effective safety system performance,
- 4) non-volatile storage of collected mishap data (one or more events) in a single, hardened unit that is located to be readily-retrievable adjacent to an aircraft egress route after a mishap,
- 5) integration into the aviation platform without airframe modification other than physical attachment of sensors or other hardware,

- 6) operation without access to aircraft power (if possible),
- 7) operation in the Naval aviation flight environment [Refs 3, 4], and
- 8) being produced at a price target of less than \$10k per unit.

The designed capability does not need to include the activation of active crash protective devices; the system should simply provide a local output indicating detection of a probable mishap event. In addition, the algorithms and thresholds associated with mishap detection should be reprogrammable to accommodate a variety of future active safety systems such as restraint pretensioners or air bag systems.

Notionally, the desired capability should not require access to aircraft power or recharging of batteries for 60 flight hours. Additionally, the system may not weigh more than 5 lbs. or have an overall volume of greater than 125 cubic inches.

PHASE I: Design, develop and demonstrate feasibility of a crash recording and detection system as outlined in the Description. Identify and document the trade space associated with the proposed performance requirements, including projected system cost. Develop and determine technical feasibility of approaches that minimize airframe integration challenges (SWaP), and support implementation on legacy platforms. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Further develop, test, and demonstrate a prototype system that is capable of achieving the requirements provided for Phase I. Perform validation and verification through a combination of analysis, laboratory testing, and potential full-scale aircraft crash testing and operational flight test. Minimizing the potential for false crash detection events, which could potentially result in the activation of active safety systems, is a focus.

PHASE III DUAL USE APPLICATIONS: Complete design iteration and system testing. Mature the unit for transition to Naval Aviation platforms and commercial users. Crash sensing and recording systems capable of retrofit into aircraft have significant general and commercial aviation applications. Current “black box” or Digital Flight Data Recorder requirements only require aircraft accelerations to be measured at relatively low sample rates, which are insufficient for triggering or recording mishap dynamics. The collection of high-sample rate data would vastly improve aviation mishap investigation, and enable future crash protective technologies. This innovative system will enable rapid and more accurate accident reconstruction and facilitate a more targeted initial focus on the actual crash scenario. Over time, the collection of mishaps will begin to form a statistical basis that will allow critique and potential revision of existing regulations regarding crash injury mitigation based on real world experience. In addition, retrofit capable active safety systems (such as inflatable restraints or pretensioning restraint retractors) typically rely on local measurement of system accelerations. The advantage of an integrated, distributed system that measures accelerations at multiple points on the airframe is the potential for earlier crash detection and improved mishap survivability. The technology that would be developed and matured during this effort has the potential to benefit general and commercial aviation.

REFERENCES:

1. Hall, B., Willis, R. & Bark, L. “Demonstration of Aviation Mishap Reconstruction with On-Board Crash Recording Technologies.” American Helicopter Society, Forum 73, 2017.
<https://vtol.org/store/product/demonstration-of-aviation-mishap-reconstruction-with-onboard-crash-recording-technologies-12040.cfm>
2. “Aircraft Crash Survival Design Guide (Vol. I, Publication No. USAAVSCOM TR-89-D-22A).” Applied Technology Laboratory, AVRADCOM, Simula Inc.: Fort Eustis, VA, 1989.
<https://apps.dtic.mil/dtic/tr/fulltext/u2/a218434.pdf>.

3. 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/

4. MIL-STD-461G, DEPARTMENT OF DEFENSE INTERFACE STANDARD: REQUIREMENTS FOR THE CONTROL OF ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF SUBSYSTEMS AND EQUIPMENT (11-DEC-2015). http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-461G_53571/

KEYWORDS: Crash Protection, Data Acquisition, Safety Systems, Mishap, Crash, Event Recorder

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)
TECHNOLOGY AREA(S): Air Platform

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 packaging and/or construction method for stowing aerial refueling hoses that reduces the space required to stow the hose on tanker aircraft, while maintaining fuel flow and structural performance requirements.

DESCRIPTION: Aerial refueling (AR) is the process of transferring fuel from one aircraft to another during flight. The AR process enables important benefits beyond simply extending the range and the time the receiving aircraft can remain airborne, such as reducing fuel weight during takeoff, in turn, providing capabilities for shorter take-off rolls and greater takeoff payloads. The United States Navy (USN) primarily employs probe-and-drogue AR systems on its tanker and receiver aircraft. For organic carrier-based tankers, the USN utilizes the Aerial Refueling Store (ARS) 31-301-48310 or “buddystore” on the F/A-18 tanker, which is also a probe-and-drogue system. In these systems, a drogue is extended from the tanker on a length of refueling hose. The drogue provides stabilization and houses the reception coupling to which the receiver aircraft engages in flight. As new tanker and receiver aircraft come online, the need for longer hoses along with the need for more aerodynamic (lower drag) aerial refueling stores is forcing the USN to evaluate new methods of storing and extending the refueling hoses in tanker aircraft. The goal is to reduce the space required to stow the hose (which will allow more hose in a same space envelope or a smaller store design) while not negatively impacting fuel flow performance. The hose must be compatible with the USN ARS and the receiver end of the hose must be compatible with the coupling interface as defined in MIL-PRF-81975 [Ref 3].

Key areas of performance to assess will be the ability to react/absorb the load during receiver engagements up to 10 feet/second and to handle the repeated stresses of extensions, retractions, stowage, and engagements. Current cycle requirement is 500 cycles without replacement. The system should include the ability to jettison (cut) the hose in flight as a failure mode. Fuel flow performance of up to 350 Gallons per Minute (GPM) (at 60 Pounds per Square Inch (PSI)) should not be impacted and should be assessed. The design should not increase fuel flow velocities to the point where surge pressure will exceed 120 PSI. Keeping velocities below 20 feet/second is generally accepted standard to minimize effects associated with static electricity. The proposer will develop an initial drawing package; and assess manufacturing plans and costs. The proposer may utilize the USN’s refueling probe impact test stand to conduct simulated engagements.

The design and analysis produced should account for the full envelope of refueling conditions:

- Altitude: Sea Level to 30,000 Ft
- Airspeed: 180-300 Knots Calibrated Air Speed (KCAS)
- Environment: Day, Night, All Weather
- Receiver Engagement Speeds: 2 to 10 feet/second
- Structural requirements of MIL-H-4495 [Ref 2]

PHASE I: Design, develop and demonstrate feasibility of proposed concept for use on the existing USN “buddystore”. Validation should be in the form of modeling and simulation, and/or lab testing. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop the concept proposed in Phase I. Define a complete set of detailed design/performance specifications for the new system to use for validation. Build a full-scale prototype and coupon test articles to assess strength, fatigue, fuel flow/pressure, and hose reel operation and engagement performance. Hose jettison analysis should be refined and/or tested.

PHASE III DUAL USE APPLICATIONS: Mature testing in flight on a tanker aircraft. Conduct Receiver Engagements to demonstrate the complete envelope, and complete component qualification to ensure design is ready for the fleet. Perform testing and transition developed technology to appropriate platforms and end users. The commercial aerial refueling industry would benefit from successful technology development.

REFERENCES:

1. “NATO Standard ATP 3.3.4.2, Air-to-Air Refueling Edition D, Version 1 April 2019.”
<https://standards.globalspec.com/std/13308207/ATP-3.3.4.2>
2. “NPFC - MIL-H-4495 HOSE ASSEMBLY, RUBBER, AERIAL REFUELING (10 MAY 1985).”
<https://standards.globalspec.com/std/929286/MIL-H-4495>
3. MIL-PRF-81975C, PERFORMANCE SPECIFICATION: COUPLINGS, REGULATED, AERIAL PRESSURE REFUELING TYPE MA-2, TYPE MA-3 AND TYPE MA-4 (22-JAN-2008)

KEYWORDS: Aerial Refueling, Refueling Hose, ARS, Refueling Store, Rubber Hoses, Composite Hoses, Flexible Hoses

N202-098

TITLE: Voice Recognition to Support Assessment of Cross Platform Situational Awareness and Decision Making

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

TECHNOLOGY AREA(S): Air Platform, Battlespace, Human Systems

OBJECTIVE: Develop a voice recognition capability that can support analysis and debrief of Carrier Strike Group level decision making and Situational Awareness (SA).

DESCRIPTION: There is a need for complex, highly coordinated, System-of-Systems, Air Defense missions and tactics cross-platform communications. The complexity of coordination associated with integrated tactics necessitates a significant amount of voice communications across the different platforms to provide SA and elicit decision-making. Communication is critical to cross platform coordination and overall tactic execution, yet it remains one of the most challenging training objectives to meet during Air Defense events. Specifically, there are challenges with recognizing when a call or request for communication has been made (i.e., at a specific point in the timeline), ensuring timeliness of communications (i.e., time to respond to a request or provide required information based on environmental cue), and providing the appropriate brevity terms and standard communications protocols. The need for timely, diagnostic feedback specific to cross-platform communications becomes critical. Current practice for assessing communications and overall performance relies solely on qualitative instructor assessments in large part due to the need to understand what is being said, and the context of the situation it is being said in. Challenges are associated with human error, manpower, and time resources required to meet training demands. In addition, debriefs can take thirty to ninety minutes to prepare, which can create potential loss of learning points. Consequently, the need for reliable (i.e., consistently, accurately captures what was said), timely (i.e., data can be synthesized and used for debrief within thirty minutes or less) and diagnostic feedback (i.e., data provided allows instructors to correlate voice communication with tactical execution to provide relevant feedback based on environmental context) for voice communication that can be standardized across platforms is important. A proof-of-concept to demonstrate the ability to create logs and a plan for prototype development and implementation and evolve into a demonstrable capability integrated into the Next Generation Threat System's (NGTS) Analysis and Reporting Tool (ART). In order to integrate with ART, a voice tool would have to provide a parse-able "utterance log" in a compatible format (e.g., json, xml, hdf5) that could log individual utterances with metadata (e.g., start/end time, sender/receiver, text transcript).

The development of an innovative speech recognition tool for cross-platform SA and decision-making will benefit the Fleet by significantly decreasing instructor workload, reducing human error and manpower time requirements, and automatically provide instructors with information on communication protocol adherence and timeliness to improve SA and increase debriefing capabilities. The tool should analyze virtual, and eventually live training events, using speech to text (STT) technologies and natural language processing (NLP) to verify automatically the semantic content of utterances associated with relevant tactical communications. It should provide a parse-able "utterance log" of these utterances to include things like start/end time, sender/receiver, text that accurately captures voice communication, etc., allowing the communications data to be linked to objectively captured contextual cues within the tactical environment (e.g., threat location). Applying this type of technology to Air Defense integrated training will enhance assessment by providing more robust and accurate assessments. The tool will allow for natural, free flowing interactions between platforms, which will result in speech recognition and understanding among groups within context. Additionally, the tool should be designed and developed to include debrief visualizations that support diagnosis and feedback of voice communication tied to context in the tactical environment at the time of the communication. Visualizations should also account for timeliness and accuracy. The tool should be easy to use as determined by usability and technology evaluations that should be documented.

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. 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: Define and develop a concept for standalone, voice assessment capability for a single Air Defense platform. Demonstrate feasibility of application into the larger, integrated training system. The concept should include a plan for integration into the NGTS ART to allow voice feedback/assessment to be aligned with unclassified performance data from NGTS Ch.10 log files (to be provided as GFI) and include assessment visualizations to support diagnosis and feedback. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and demonstrate a prototype voice assessment capability for a single Air Defense platform through execution of the integration plan developed in Phase I. Integration with NGTS ART will enhance the capability by aligning voice feedback with performance data already collected by the ART. Design and develop the prototype to include visualizations, usability documentation, and technology evaluation.

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

PHASE III DUAL USE APPLICATIONS: Extend functionality to multiple platforms integrated in NGTS ART. Final testing and transition will include regression tests, bug fixes, and patching as required by the NGTS ART transition customer to support the Integrated Training Facility's requirements. Perform an in-depth evaluation of the training effectiveness of the tool and provide return on investment information for program acquisition. Expand to include application of the baseline capabilities to other mission sets and domains as needed.

Development of a voice recognition suite that includes performance and visualizations integrated with various pilot simulations allows for a modular capability. This technology could be used for commercial pilot training as well as other team-based domains, which focus heavily on communication and coordination, particularly within the aviation domain (e.g., Air Traffic Control).

REFERENCES:

1. Ahmed, U.Z., Kumar, A., Choudhury, M., and Bali, K. "Can Modern Statistical Parsers Lead to Better Natural Language Understanding for Education?" Computational Linguistics and Intelligent Text Processing, 7181, 2012, pp. 415--417. <https://www.cse.iitk.ac.in/users/umair/papers/cicling12.pdf>
2. Deng, L. & Xiao, L. "Machine Learning Paradigms for Speech Recognition: An Overview." IEEE Transactions on Audio, Speech, and Language Processing, vol 21, no 5, 2013. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.337.8867&rep=rep1&type=pdf>
3. Jurafsky, D. and Martin, J.H. "Speech and Language Processing. Cambridge, MA: MIT Press, 2008. <https://www.cs.colorado.edu/~martin/SLP/Updates/1.pdf>

4. Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E. & Cannon-Bowers, J. A. "The Influence of Shared Mental Models on Team Process and Performance". *Journal of Applied Psychology*, 85(2), 2000, p. 273. https://www.ida.liu.se/~729A15/mtrl/shared_mental-models_mathieu.pdf
5. Shneiderman, B. "The Limits of Speech Recognition." *Communications of the ACM*, 43(9), 2000. <https://www.cs.umd.edu/users/ben/papers/Shneiderman2000limits.pdf>
6. Stensrud, B., Taylor, G. and Crossman, J. "IF-Soar: A Virtual, Speech-Enabled Agent for Indirect Fire Training." *Proceedings of the 25th Army Science Conference*, Orlando, FL., November 27-30, 2006. <https://www.cs.umd.edu/users/ben/papers/Shneiderman2000limits.pdf>
7. Traum, D. R. & Hinkelman, E. A. "Conversation Acts in Task-Oriented Spoken Dialogue." *Computational Intelligence Special Issue: Computational Approaches to Non-Literal Language*, vol 8, no 3, 1993. <https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-8640.1992.tb00380.x>
8. Zaihrayeu, I., Sun, L., Giunchiglia, F., Pan, W., Ju, Q., Chi, M. & Huang, X. "Web Directories to Ontologies: Natural Language Processing Challenges." Springer: Berlin Heidelberg, pp. 623-636. <http://iswc2007.semanticweb.org/papers/617.pdf>

KEYWORDS: Speech To Text, STT Technologies, Natural Language Processing, NLP, Tactical Speech, Decision Making, Speech Recognition, Voice Recognition

N202-099

TITLE: Implementing Neural Network Algorithms on Neuromorphic Processors

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Deploy Deep Neural Network algorithms on near-commercially available Neuromorphic or equivalent Spiking Neural Network processing hardware.

DESCRIPTION: Biological inspired Neural Networks provide the basis for modern signal processing and classification algorithms. Implementation of these algorithms on conventional computing hardware requires significant compromises in efficiency and latency due to fundamental design differences. A new class of hardware is emerging that more closely resembles the biological Neuron/Synapse model found in Nature and may solve some of these limitations and bottlenecks. Recent work has demonstrated significant performance gains using these new hardware architectures and have shown equivalence to converge on a solution with the same accuracy [Ref 1].

The most promising of the new class are based on Spiking Neural Networks (SNN) and analog Processing in Memory (PiM), where information is spatially and temporally encoded onto the network. A simple spiking network can reproduce the complex behavior found in the Neural Cortex with significant reduction in complexity and power requirements [Ref 2]. Fundamentally, there should be no difference between algorithms based on Neural Network and current processing hardware. In fact, the algorithms can easily be transferred between hardware architectures [Ref 4]. The performance gains, application of neural networks and the relative ease of transitioning current algorithms over to the new hardware motivates the consideration of this topic.

Hardware based on Spiking Neural Networks (SNN) are currently under development at various stages of maturity. Two prominent examples are the IBM True North and the INTEL Loihi Chips, respectively. The IBM approach uses conventional CMOS technology and the INTEL approach uses a less mature memristor architecture. Estimated efficiency performance increase is greater than 3 orders of magnitude better than state of the art Graphic Processing Unit (GPUs) or Field-programmable gate array (FPGAs). More advanced architectures based on an all-optical or photonic based SNN show even more promise. Nano-Photonic based systems are estimated to achieve 6 orders of magnitude increase in efficiency and computational density; approaching the performance of a Human Neural Cortex. The primary goal of this effort is to deploy Deep Neural Network algorithms on near-commercially available Neuromorphic or equivalent Spiking Neural Network processing hardware. Benchmark the performance gains and validate the suitability to warfighter application.

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. 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: Develop an approach for deploying Neural Network algorithms and identify suitable hardware, learning algorithm framework and benchmark testing and validation methodology plan. Demonstrate

performance enhancements and integration of technology as described in the description above. The Phase I effort will include plans to be developed under Phase II.

PHASE II: Transfer government furnished algorithms and training data running on a desktop computing environment to the new hardware environment. An example algorithm development frame for this work would be TensorFlow. Some modification of the framework and/or algorithms may be required to facilitate transfer. Some optimization will be required and is expected to maximize the performance of the algorithms on the new hardware. This optimization should focus on throughput, latency, and power draw/dissipation. Benchmark testing should be conducted against these metrics. Develop a transition plan for 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: Optimize algorithm and conduct benchmark testing. Adjust algorithms as needed and transition to final hardware environment. Successful technology development could benefit industries that conduct data mining and high-end processing, computer modeling and machine learning such as manufacturing, automotive, and aerospace industries.

REFERENCES:

1. Ambrogio, S., Narayanan, P., Tsai, H., Shelby, R., Boybat, I., Nolfo, C., . . . Burr, G. “Equivalent-Accuracy Accelerated Neural-Network Training Using Analogue Memory.” Nature, June 6, 2018, pp. 60-67. <https://www.nature.com/articles/s41586-018-0180-5>
2. Izhikevich, E. “Simple Model of Spiking Neurons.” IEEE Transactions on Neural Networks, 2003, pp. 1569-1572. <https://ieeexplore.ieee.org/document/1257420>
3. Diehl, P., Zarella, G., Cassidy, A., Pedroni, B. & Neftci, E. “Conversion of Artificial Recurrent Neural Networks to Spiking Neural Networks for Low-Power Neuromorphic Hardware.” Cornell University, 2016. <https://arxiv.org/abs/1601.04187>
4. Esser, S., Merolla, P., Arthur, J., Cassidy, A., Appuswamy, R., Andreopoulos, A., . . . Modha, D. “Convolutional Networks for Fast, Energy-Efficient Neuromorphic Computing.” IBM Research: Almaden, May 24, 2016. <https://arxiv.org/pdf/1603.08270.pdf>
5. Department of Defense. National Defense Strategy 2018. United States Congress. <https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>

KEYWORDS: Neural Networks, Neuromorphic, Processor, Algorithm, Spiking Neurons, Machine Learning

N202-100 TITLE: Preload Indicating Hardware for Bolted Joints

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

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Develop a method of determining preload on aircraft bolted joints through a visual indication, or alternate means, which does not require physical measurement of torque via a torque wrench and does not require disassembly of any adjacent parts.

DESCRIPTION: Helicopters experience high amounts of vibration and as a result, the onboard equipment experiences different frequency resonances that cause bolted joints to loosen during operation. Torque checks are one of the regularly performed maintenance actions to make sure fasteners are still within designated torque values, and that no bolted joints have loosened over the operational life of the aircraft.

Preload Indicating Hardware is hardware in a bolted joint assembly that gives the user a visual indication that proper tension/torque is applied. Examples in industry for industrial/commercial hardware applications range from one-time use washers with visual indicators to stress indicating bolts that contain a visual coloring or scale indication. Unlike torque checks where the clamping force is approximated via the resistance of the spinning bolt, this type of hardware directly measures clamping force in the bolted joint. Current available products would need to size down to accommodate aircraft application and show that the torque indication accuracy is within the desired parameters.

Another method of determining preload on a bolted joint without the use of a torque wrench or other tool to turn the bolt is the use of ultrasound technology. Ultrasound technology generally involves a probe that emits ultrasonic waves into a material and analyzes the reflection of said waves to determine the characteristics of the material. The clamping force of a bolted joint can be determined through this method by analyzing the amount of strain a bolted joint is exerting on a part. This method of inspection can often require physical contact with the bolted joint, but compared to using a torque wrench, one only needs enough space for the probe to make contact versus space for a full wrench turn. This technology would have to be adopted to detect loss of preload on varying sized hardware to limit the need to manufacture multiple tools and reduce possible maintainer training.

Current torque checking procedures require maintainers to expose the bolts to the degree that space permits free engagement of a torque wrench. After re-installation and the torque check, a vibration check and a functional check flight (FCF) are often required, which take multiple maintenance man-hours to complete. These maintenance man-hours exponentially accumulate in the event a torque check fails or subsequently doesn't pass the vibration check and/or FCF on the first round, affecting overall aircraft readiness. This is where preload indicating hardware could be a significant game changer in reducing maintenance man-hours for torque verification. This technology would give the maintainers a visual indication of whether or not a fastener is still exerting the required amount of preload in a bolted joint, and would eliminate a significant amount of non-mission capable hours (NMCH) and maintenance man-hours required as part of a physical torque verification process.

A product (preload indicator) is needed that can be easily implemented onto existing Navy/Marine aircraft, without major modifications to any part of the structure or any other components on the aircraft. The preload indicator can be built into the bolt, the nut, the washer, or any combination of the three as long as the design does not hinder current torque check procedures, or can be a separate tool so long as it does not damage any surrounding components. The hardware should be able to accommodate bolts as small as 0.375-inches in diameter to as large as 1.6875-inches in diameter. Binary preload indication

should be visible enough that maintainers can clearly see an out-of-torque and over-torqued bolt during night conditions typical of ship-based operations. It should be able to withstand flight conditions/loads without loss of preload in the bolted joint over the life of the aircraft for airframe application, or the predefined maintenance interval for dynamic components. The product should be able to endure corrosion prone environments typical of naval operations, vibrations, and accommodate temperatures typical of naval aircraft (details will be provided to Phase I awardees). Debris commonly found inside the aircraft (i.e., hydraulic fluid, gearbox fluid, etc.) should not affect preload indication. Handling and fall damage should not cause the product to lose accuracy. The preload of the current bolted joints should remain the same, as well as keeping to the currently implemented fastener standards. Additional installed hardware on the aircraft should be no more than a combined weight of two pounds. The hardware must have negligible effect (+/-5%) on the natural frequency of the fasteners as to not interfere with the existing health monitoring sensors. Implementation of this hardware should also not introduce new failure modes. Wireless inspection solutions of bolted joint preload must be consistent and accurate. Parts adjacent to the designated bolted joints should not require removal in order for the tool to properly inspect bolt preload.

PHASE I: Develop and design a preload indicator for bolted joints that provides a binary indication of torque value. Ensure that the selected indicator methods have no intrinsic limitations to scaling with the bolt sizes described in the Description. Demonstrate the feasibility of the indicator showing a path forward to meeting Phase II goals. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and build a prototype that can successfully provide indication that a bolted joint, through a visual cue, a tool, or otherwise, has either lost preload, or been over torqued. Demonstrate non-destructive inspection of the bolted joint complies with Naval Aviation standards. Demonstrate that the prototype will withstand handling and fall damage without losing accuracy.

PHASE III DUAL USE APPLICATIONS: Verify and validate the viability of the prototype at a fleet maintenance facility and in the field. Transition the prototype into a final product for Navy/Marine Corp fleet application. Distribute the product, support equipment, and process specifications to maintainers. Commercial applications include structures (e.g., factories, bridges, and buildings), transportation equipment, and commercial aircraft.

REFERENCES:

1. Chambers, Jeffrey. "Preloaded Joint Analysis Methodology for Space Flight Systems." National Aeronautics and Space Administration, 1995.
<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19960012183.pdf>
2. Chapman, I., Newnham, J., and Wallace, P. "The Tightening of Bolts to Yield and Their Performance Under Load." ASME. J. Vib., Acoust., Stress, and Reliab. April 1986, 108(2), pp. 213-221.
<https://doi.org/10.1115/1.3269326>
3. Chen, S. H., He, Z. G. & Egger, P. "Study of Hollow Friction Bolts In Rock By a Three Dimensional Composite Element Method." International Society for Rock Mechanics and Rock Engineering, January 1, 2003. <http://www.onepetro.org/conference-paper/ISRM-10CONGRESS-2003-035>
4. "Fatigue Tests on High Strength Bolts and 'Coronet' Load Indicators." TurnaSure, LLC.
<http://www.turnasure.com/pdf/reports/26%20Fatigue%20Tests.pdf>

KEYWORDS: Preload, Torque, Bolt, Hardware, Wireless, Inspection

N202-101

TITLE: Data Link Bottleneck Reduction Using Big Data Analytics

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop innovative approaches utilizing big data analytics techniques to identify and extract critical content from sensor imagery products to reduce data-link bandwidth requirements dramatically, while maintaining or improving the rate at which actionable intelligence is generated.

DESCRIPTION: Navy imaging sensors, like optical, electro-optical, multispectral, hyperspectral, and radar sensors, are producing so much high-quality imagery that it overwhelms on-aircraft data link resources. Techniques to buffer, preprocess and compress data are incrementally improved as are the capabilities of data link hardware but these are not keeping pace with sensor improvements that are leading to a continuous rise in data traffic. This situation exists for both line of sight and beyond line of sight links. Significant research is underway in big data analytics techniques to facilitate rapid, more informed and smarter decision making when faced with vast and overwhelming quantities of information. This SBIR topic seeks to use those tools to analyze and extract critical content from imagery products generated by various sensor systems onboard the aircraft. The operational need for this is critical for unmanned aircraft but certainly not limited to those platforms. The big data analytics toolbox contains a range of techniques for the extraction of features, the automatic parsing, segmenting, indexing and tagging of critical imagery content. Multiple synergistic artificial intelligence (AI) techniques are being utilized to inform those actions in ways to best serve the user's needs. This SBIR topic seeks to leverage these techniques to better serve time critical military operations.

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. 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: Demonstrate how big data analytics techniques could in principle be used to dramatically reduce data link bandwidth requirements while maintaining or improving the rate at which actionable intelligence is generated. Reductions on the order of 10x threshold and 100x objective are being sought. The scope of the demonstration can be rather limited but must be operationally relevant and sufficient to show feasibility of the proposed approach. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Complete detailed development and demonstrate an end-to-end approach for the intelligent real-time automated extraction of critical sensor imagery products from imaging sensors, like optical, electro-optical, multispectral, hyperspectral, and radar. Show how this will dramatically reduce data-link bandwidth requirements while maintaining or improving the rate at which actionable intelligence is generated.

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

PHASE III DUAL USE APPLICATIONS: Refine the solution, perform final testing, and integrate and transition the final solution to Navy airborne platforms. Typical host computational platforms are Ion Intel® Xeon® Scalable processors and successors with greater than 10 TB SSD storage.

The big-data analytics as applied to data-link information management are applicable to a wide range of applications including law enforcement and border-control surveillance operation.

REFERENCES:

1. Schulte, M. "Real-time feature extraction from video stream data for stream segmentation and tagging." Diplomarbeit, Dortmund, January 22, 2013. http://www-ai.cs.tu-dortmund.de/schulte_2013a.pdf?self=%24dv5v9puha8&part=data
2. Griethe, W. "Advanced Broadband Links for Tier III UAV Communication." DASIA 2011, San Anton, Malta, May 2011. https://www.researchgate.net/publication/261727128_ADVANCED_BROADBAND_LINKS_FOR_TIER_III_UAV_DATA_COMMUNICATION

KEYWORDS: Big Data Analytics, Data Links, Information Management, Radar, Electro-Optics, Data Mining, Artificial Intelligence, AI

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

TECHNOLOGY AREA(S): 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: Develop a direct drive power amplifier with a controllable output for an A-size source sonobuoy to mature the latest technologies and achieve significant improvements in the capabilities of source sonobuoys.

DESCRIPTION: A-size sonobuoys currently in use by the Navy require improvement in order to detect the quieter power and propulsion systems of modern vessels. The Navy desires higher sound pressure levels, a broader frequency band (400-600Hz), and a smaller volume (< 35 in. cubed) than today's traditional architectures, as well as a new power amplifier architecture that enhances the performance and capability of an A-size sonobuoy suitable for a future variant of the AN/SSQ-125.

The power amplifier must have the capability to drive the sonobuoy source over a frequency band of 600 to 1100 Hz. The electrical rating [Refs 3, 4] of the amplifier should be adequate for it to withstand the power draw by the system without an electrical breakdown or mechanical failure (thermal failure). The power amplifier should provide a clean output to the system with a very low harmonic distortion. Today's active sonobuoys are key for the Navy in detecting and tracking targets of interest. However, the range of detection and resolution are limited by the source operational performance. A broader operational bandwidth will allow simultaneous search in multiple sub-bands. As the latest source sonobuoys have tight packaging constraints, a new power amplifier architecture that reduces the volume (< 35 in. cubed approximately equal to Diameter: 4in., Height: 3in.), along with an augmentation in capability, is a future source sonobuoy enabler.

The power amplifier must be designed so that it can be easily integrated into an A-size sonobuoy. The purpose of this SBIR topic is to design and develop an amplifier that can eventually be incorporated into an AN/SSQ-125. It is recommended to work with the AN/SSQ-125 sonobuoys vendors to understand all the performance specifications and the interface requirements so that the new power amplifier design can be easily integrated into the sonobuoy for demonstration purposes.

The key performance objectives of this drive system are as follows:

- Validate the packaging fit within a volume of 35 in. cubed (Diameter: 4in., Width: 3 in.) (threshold) or in less volume (objective).
- Validate the control can sweep the power output to operate over the specified frequency band.
- Validate the power amplifier can provide the load required by the transducers.
- Battery Output: (5000 W, 50 A, 117 Voc, 5 Ah)
- Transducers: (800 – 1100 Vrms)
- Validate it can provide a clean output: Self Noise < 25 dB and THD as follows:

Harmonics	Normal Operating	Power Level at Full Power
Second	-16 dB	-25 dB
Third	-30 dB	-40 dB
Fourth and above	-50 dB	-60 dB

Specifications Requirements:

- The amplifier electrical performance should be tested accordingly to DOD standards (MIL-STD-202G [Ref 3] & MIL-STD-883K [Ref 4])
- The amplifier must meet DOD electromagnetic compatibility standards (MIL-STD-461G [Ref 5] & MIL-STD-464C [Ref 6])
- The amplifier must be waterproof and manufacture tailored to sonobuoy environments. (MIL-STD-810H [Ref 7])
- The amplifier must be able to withstand a depth of 65 – 1000ft (65 -500ft threshold) (MIL-STD-1522 [Ref 8])

Although not required, it is highly recommended that the performer to work in coordination with the original equipment manufacturer (OEM) to ensure proper design and to facilitate transition of the final 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). 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 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 advance phases of this contract.

PHASE I: Design and develop a power amplifier with a new architecture for an AN/SSQ-125 sonobuoy. The design approach must be compatible with the existing AN/SSQ-125, including the interfaces with the battery and the projector elements. It must fit within the current volume within the AN/SSQ-125. The complete approach that will be pursued must be established in Phase I. Appropriate analyses and top-level drawings should be provided. Demonstrated the design is feasible and cost effective for production. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Finalize the design, manufacture, and validate that the new design of the power amplifier meets the specified requirements using a power source and dummy loads. Integrate it into an AN/SSQ-125. Demonstrate its performance in an underwater test at NAVSEA Seneca Lake Sonar Test Facility at Dresden, N.Y. using five AN/SSQ-125 sonobuoys. If necessary, make adjustments to the design, fabricate revised prototypes, and repeat the testing and model verification regime.

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: Continue to refine and test extensively the fabricated prototype, including testing for severe environmental conditions. Revamp the new power amplifier as required and develop the design for manufacturing. Develop low-rate initial production prototypes for follow-on Government testing.

Successful technology development would benefit all U.S. Navy source sonobuoys as well as underwater oil and gas equipment operation monitoring. This technology could also be a cost reduction for the price of the source sonobuoy and would provide significant ROI on the many years of follow-on source sonobuoy production (as per buoy price savings) on the invested SBIR funds. This innovation could be used by the audio industry (headphone amplifiers), the geography industry (terrain mapping equipment), and academia (ocean studies, bathymetry, etc.)

REFERENCES:

1. Holler, R.A., Horbach, A.W. and McEachern, J.F. "The Ears of Air ASW – A History of U.S. Navy Sonobuoys." Navmar Applied Sciences Corporation, 2008. <https://www.worldcat.org/title/ears-of-air-asw-a-history-of-us-navy-sonobuoys/oclc/720627294> or https://books.google.com/books/about/The_Ears_of_Air_ASW.html?id=VKP-twEACAAJ
2. Sherman, C.H., and Butler, J. "Transducers and Arrays for Underwater Sound." Springer Science+Business Media, 2007. ISBN:978-0-387-32940-6. <https://link.springer.com/book/10.1007/978-0-387-33139-3>
3. MIL-STD-202H (CONSOLIDATED), DEPARTMENT OF DEFENSE TEST METHOD STANDARD: ELECTRONIC AND ELECTRICAL COMPONENT PARTS (18-APR-2015) http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-202H_CONSOLIDATED_18APR2015_52148/
4. MIL-STD-883K (w/ CHANGE-3), DEPARTMENT OF DEFENSE TEST METHOD STANDARD: MICROCIRCUITS (03-MAY-2018) http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883K_CHG-3_55826/
5. MIL-STD-461G, DEPARTMENT OF DEFENSE INTERFACE STANDARD: REQUIREMENTS FOR THE CONTROL OF ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF SUBSYSTEMS AND EQUIPMENT (11-DEC-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 (01 DEC 2010) http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-464C_28312/
7. 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/
8. MIL-STD-1522A, MILITARY STANDARD: STANDARD GENERAL REQUIREMENTS FOR SAFE DESIGN AND OPERATION OF PRESSURIZED MISSILE AND SPACE SYSTEMS (28-MAY-1984) http://everyspec.com/MIL-STD/MIL-STD-1500-1599/MIL_STD_1522A_1429/

KEYWORDS: Active Sonobuoy, Anti-Submarine Warfare, ASW, AN/SSQ-125, Direct Drive Amplifier, A-size

N202-103

TITLE: Software Toolset for Rapid Finite Element (FE) Mesh Generation of As-Built Large Laminated Composite Structural Components

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

TECHNOLOGY AREA(S): Air Platform, Materials

OBJECTIVE: Develop a software toolkit enabling automated generation of Finite Element (FE) meshes to rapidly assess structural capability of as-built and damaged composite structures from Computed Tomography (CT) scan data that accurately captures ply layers, ply-orientations, ply drops, and fiber-resin densities. The mesh should include manufacturing defects such as waviness, air pockets, porosities, and other CT-revealed observable anomalies/defects/damages.

DESCRIPTION: Advanced rotors for vertical lift aircraft and wings on many U.S. Navy fixed wing aircraft are complex assemblies made primarily from composites. CT scans can provide the foundation for analyses of these structures that accurately model manufacturing defects and the quality of a repair. The references cited demonstrate algorithm technologies capable of transitioning CT scans into composite structural FE models. An FE model that accurately captures the in-situ condition of a questionable manufactured part will improve speed, accuracy and consistency in disposition instructions for these non-conforming wings and rotor blades. An FE model that accurately captures the in-situ condition of a new repair will provide stress and strain comparisons to adjacent authorized high stress locations of identical materials. The span of flaw sizes between what is acceptable and what is unacceptable is very large in complex composite structures. Converting the CT scans with authorized manufacturing defects into an FE mesh will provide an analytical stress threshold for assessing these gray areas and for developing repairs to the scanned component. The proposed solution should address the following key requirements:

- A. The ability to generate accurate subsurface geometry data for a composite structure that includes all manufacturing defects such as wrinkles and voids at ply interfaces.
- B. The ability to automate the conversion from geometry data to structural FE models, where the structural FE models will reveal the influence of these defects on strength and fatigue performance for do-no-harm repairs, life-improvement design changes, and disposition instructions.

The finite element mesh must be applicable to progressive damage analysis of laminated composite structure including manufacturing defects such as wrinkles, marcells, foreign object debris, and ply interface voids. Besides developing possible repairs for field-damaged components, brand new parts will benefit from this software toolkit. Manufacturing processes used to produce thick composite structures can generate defects that could impact their performance and service life. Determining disposition instructions for these new components involves Material Review Board (MRB) efforts that can be long and tiresome. Existing tools used to measure defects with the attempted recreation of these defects in test coupons can result in a perpetually delayed decision about the part's acceptability. The difficulty in assessing defects may result in storing the rotor blades or wings in a warehouse until technological capabilities become available to determine what actions to take: scrap, repair, or sell as-is.

Rapidly built structural diagnostic FE models for evaluating structural integrity using an automated interpretation of the nondestructive measurement data will fill a necessary technological need. FE modeling of the entire data-driven blade or wing assembly will assist in determining the margins of safety for flight qualification. CT conversion of field-damaged large parts to an FE model that captures undamaged adjacent authorized manufacturing defects will provide stress limit thresholds for safely establishing repairs to the component scanned. CT data conversion of flawed new components will greatly assist in MRB decisions. The FE mesh can provide a model for design modifications. This project

will merge state-of-the-art nondestructive measurements with composite durability and damage tolerance analyses into an add-on toolkit package for a commercial FE software program.

PHASE I: Demonstrate a semi-automated transition of CT-based measurements of a rotor blade section or wing section to a high-fidelity FE mesh that captures the composite material structure including ply-orientations with a refined mesh surrounding the to-scale, three-dimensional manufacturing defects. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Integrate the automated analysis toolkit into a commercial finite element modeling software for use in high performance computing centers. Demonstrate progressive damage and structural fatigue analysis capability on a rotor blade or wing.

PHASE III DUAL USE APPLICATIONS: Perform full-scale testing on NAVAIR-supplied structures to validate progressive damage predictive capability. Make any corrections identified during full scale testing and finalize toolkit. Transition software toolkit into fleet overhaul facilities, fleet support teams, and OEM commercial markets.

This technology will assist aircraft, automotive, and recreational vehicle industries that use advanced composite materials. This toolkit will assess the strength of prototype composite structural designs and will identify static and fatigue test procedure limits for those prototypes. This toolkit will improve speed, accuracy, and consistency in material review board decisions on non-conforming composite parts.

REFERENCES:

1. Avril, S., Bonnet, M., Bretelle, A.-S., Grédiac, M., Hild, F., Lenny, P., & Pierron, F. "Overview of Identification Methods of Mechanical Parameters Based on Full-Field Measurements." *Experimental Mechanics*, 2008. <https://link.springer.com/article/10.1007/s11340-008-9148-y>
2. Rahmani, B., Villemure, I. & Levesque, M. "Regularized Virtual Fields Method for Mechanical Properties Identification of Composite Materials." *Computer Methods in Applied Mechanics and Engineering*, 2014, pp. 543-566. <https://www.sciencedirect.com/science/article/pii/S0045782514001558>
3. Straumit, I., Lomov, S. & Wevers, M. "Quantification of the Internal Structure and Automatic Generation of Voxel Models of Textile Composites from X-Ray Computed Tomography Data." *Composites Part A: Applied Science and Manufacturing*, 2015, pp. 150-158. <https://www.sciencedirect.com/science/article/pii/S1359835X14003625>
4. Makeev, A., Seon, G., Nikishkov, Y., Nguyen, D., Matthews, P. & Robeson, M. "Analysis Methods Improving Confidence in Material Qualification for Laminated Composites." *American Helicopter Society 72nd Annual Forum*, 2016, Semantic Scholar: West Palm Beach. <https://pdfs.semanticscholar.org/ceb7/bb7903524cacf2b958f646637175e62aaf13.pdf>
5. Nikishkov, Y., Seon, G., Makeev, A. & Shonkwiler, B. "In-situ Measurements of Fracture Toughness Properties in Composite Laminates." *Materials & Design*, 2016, pp. 303-313. <https://www.sciencedirect.com/science/article/abs/pii/S0264127516300132>
6. Lambert, J., Chambers, A., Sinclair, I. & Spearing, S. "3D Damage Characterisation and the Role of Voids in the Fatigue of Wind Turbine Blade Materials." *Composites Science and Technology*, 2012, pp. 337-343. <https://www.sciencedirect.com/science/article/abs/pii/S0266353811004155>

7. Dobyms, A., Rousseau, C. & Minguet, P. "Helicopter Applications and Design." Comprehensive Composite Materials, 2000, pp. 223-242.

<https://www.sciencedirect.com/science/article/pii/B0080429939001984>

KEYWORDS: Composite Wings, Rotors, CT Scan, Finite Element, Damage Progression, Manufacturing Defects, Composite Repairs, Computed Tomography

N202-104 TITLE: Time and Phase Synchronization of Radio Frequency (RF) Sources across Multiple Unmanned Aerial System/Vehicle (UAS/UAV) Platforms

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

TECHNOLOGY AREA(S): Air Platform, Battlespace

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 a capability to perform high-precision time and phase synchronization (phase coherency) of multiple distributed radio frequency (RF) sources located on Unmanned Aerial Systems (UASs) platforms such as Group 3 drones separated in a dynamic and Global Positioning System (GPS) denied environment.

DESCRIPTION: Small UASs have found many applications within both the defense and commercial sectors. With the increasing use of small UASs, it is desired to equip them with RF sensors/payloads to permit them to work together to form a coherent beam on a target. In order to do this, precise time synchronization among the UASs is essential. Current techniques rely on either the use of GPS or an embedded signal from the target in order to time synchronize multiple UASs. In order to be more operationally suitable, development of a solution to the time synchronization problem for multiple spatially dispersed UASs, which works in the absence of both GPS and cooperative targets is needed. Additionally, the developed solution must be able to operate in a relevant environment that can have wide ranges in temperature, vibration [Ref 7], and meet the space, weight (<100 lbs), power, and cooling (SWaP-C) requirements of a small UAS such as Group 3 [Ref 6] and typical payloads such as a datalink, an electronic warfare (EW) system, etc.

The goal is to obtain accuracy in timing (10 to 100 picoseconds) and phase coherency to within 1/10 to 1/12 of a relevant RF operating wavelength (UHF or higher band) between nodes (or between slave nodes and the master node).

The details on the methods and mechanism of obtaining coherency across all nodes in the network are requested, additionally, any special waveforms or control signals that are employed and any special oscillators required are also requested. The ability to easily integrate into existing datalinks and radio designs (specify one or more applications for a UHF, C Band, S Band, other data link using single carrier modulation, spread spectrum, or Orthogonal Frequency Division Multiplex (OFDM) or a Common Data Link (CDL) is requested. Provide details of how to integrate this into existing designs or new designs.

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. 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: Design and develop the concept and approach for time synchronization of RF sources across a distributed system. Demonstrate the feasibility of the designed approach through modeling and simulation for a swarm consisting of 10 UAS randomly distributed spatially throughout a one-mile area, and quantify the beam pointing error as a function of frequency. Include the processing blocks that provide the critical functions and include a baseline set of quantitative implementation requirements that will form the basis for further development in Phase II. Phase I will consider UAS's from Group's 1 or 2. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Refine the approach developed in Phase I. Develop prototype hardware and demonstrate the approach on 3 to 6 platforms. Include a static demonstration and then if deemed successful, end with a dynamic demonstration (i.e., quadcopters). Phase II will consider flight demonstrations from UAS Group 3 drones such as the Tigershark XP. Prepare a Phase III development plan to transition the technology for Navy and potential commercial use.

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

PHASE III DUAL USE APPLICATIONS: Refine the technology developed for easier integration into tactical data links. Install on several types of Navy UASs and deploy on larger UAS swarms. Successful technology development could benefit the Telecom and Mapping industries.

REFERENCES:

1. Mudumbai, R., Brown, D.R., Madhow, U. & Poor, H.V. "Distributed transmit beamforming: challenges and recent progress." IEEE Communications Magazine, 47, 2009, pp.102-110. DOI:10.1109/MCOM.2009.4785387
2. Comberiate, T. M., Zilevu, K. S., Hodkin, J. E. & Nanzer, J. A. "Distributed transmit beamforming on mobile platforms using high-accuracy microwave wireless positioning." SPIE Defense + Security, 2016, Baltimore, Maryland, United States. <https://www.spiedigitallibrary.org/conference-proceedings-of-spie/9829/98291S/Distributed-transmit-beamforming-on-mobile-platforms-using-high-accuracy-microwave/10.1117/12.2231793.short?SSO=1>
3. Berbakov, L. & Beko, M. "Simultaneous distributed carrier synchronization and data transmission in wireless sensor networks." 22nd Telecommunications Forum (TELFOR), 2014. <https://ieeexplore.ieee.org/document/7034405>
4. Yan, H., Hanna, S.S., Balke, K.N., Gupta, R. & Cabric, D. "Software Defined Radio Implementation of Carrier and Timing Synchronization for Distributed Arrays." 2019 IEEE Aerospace Conference, pp. 1-12. <https://ieeexplore.ieee.org/abstract/document/8742232>
5. Moreira, P., Serrano, J., Wlostowski, T., Loschmidt, P. & Gaderer, G. "White rabbit: Sub-nanosecond timing distribution over Ethernet." 2009 International Symposium on Precision Clock Synchronization for Measurement, Control and Communication, pp. 1-5. <https://ieeexplore.ieee.org/document/5340196>
6. "Classification of the Unmanned Aerial Systems." Penn State Department of Geography, College of Earth and Mineral Sciences. <https://www.e-education.psu.edu/geog892/node/5>

7. "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: Swarm, Timing, Phase, Coherent, UAV, Unmanned Aerial Vehicles, Beamforming,
Unmanned Aerial System, UAS

N202-105

TITLE: Digital Twin Technologies to Improve Mission Readiness and Sustainment

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Demonstrate the application of digital twin technologies by developing a virtual model of any naval aircraft product, derive benefits (such as predictive capabilities), and show its impact on total life cycle cost of the product. The models representing any naval aircraft product must allow real-time monitoring of performance and facilitate in-flight service of the product.

DESCRIPTION: A need exists for digital twin technologies, which allows the digital footprint of any product to permeate from design inception, through development, sustainment, and finally to disposal (i.e., the entire product lifecycle). Digital twin technology is viable and allows access to the digital image of the asset in real time, leading to secure actionable information that will improve a process, product, or service of any organization [Ref 1].

The concept has been around for a while, as shown during the disaster of the Apollo 13 mission. NASA demonstrated the technology with a mirrored system on the ground, which rescued the flight, and is further illustrated in Reference 2. Digital twin technology involves creating a virtual representation of a physical product. Digital twins are powered by machine learning algorithms and are continuously learning systems. The products are connected in a cloud-based environment that receives the data from the sensors. The input data is analyzed and compared to the organization's baseline data to identify actionable information. The goal for the digital twin technology is to create, test, and build a product in a virtual environment and demonstrate improved product design, monitor product health to identify potential degradation, and simulate manufacturing processes. This will allow real-time monitoring and preventive maintenance of the product, which will reduce product life cycle costs. In the future, every physical product will have a virtual replica (model) hosted in the cloud and enriched every day with operational data to make the model more robust.

Currently, model-based system engineering (MBSE) approaches, which move the record of authority from documents to digital models managed in a data-rich environment, are used to build products. MBSE approaches enable organizations to understand design change impacts, communicate design intent, and analyze and predict product design before it is built. System architecture models are developed when MBSE integration occurs across multiple domains such as program management, product support, manufacturing (involving analytical), verification, software, and mechanical and electrical models.

Advancements in information technologies (such as computational capabilities, the internet, cloud environment, internet of things enabled by sensors with connectivity and bandwidth factors, and cyber communication) are making the virtual space significant; in this virtual space, analog data from the physical space is converted into digital data that can be easily stored, analyzed, and displayed. Currently, there are huge gaps in the information technologies mentioned; therefore, significant research and development is needed. The combination of information technologies with MBSE enables digital twin technologies [Ref 3].

Digital twin technology is not widespread due to the requirements of prohibitive computing power needs, accessibility, bandwidth, and storage issues. Lack of robust data analytics aided by artificial intelligence, machine learning techniques, and visualization tools is impeding technology development. Digital twin technology has the potential to improve supply chain integrity, flight safety, in-flight service, condition-based maintenance, foreign object detection, and predictive maintenance. For example, developing any predictive maintenance algorithm requires sensor data, which can be utilized to train a classification

algorithm for fault detection. This algorithm is used for verification and is installed as a code to the control unit of the product. It is nearly impossible to create the fault conditions necessary for training a predictive maintenance algorithm on the actual product. A solution to this challenge is to create a digital twin of the product (a model), and apply simulation and analysis of sensor data for various fault conditions. A neural network detects abnormal patterns of the sensor data, reflects the trends in predictive models, which are then used to predict failures, and allows tests for all fault conditions with severity. The entire procedure should be automated, thereby allowing tests of “what-if” scenarios on the digital twin model.

Predictive maintenance helps to determine when an aircraft product needs maintenance. It reduces downtime and prevents product failure by enabling maintenance to be scheduled based on the actual need rather than at predetermined intervals. It can be used to calculate maintenance-related parameters (MTBF – Mean Time between Failures), forecast the behavior of the product under different circumstances, and simulate different maintenance scenarios. Thus, predictive maintenance capability helps to extend the product life and reduce total ownership costs. Collectively, it will contribute to improving the Navy’s mission readiness and sustainment significantly.

It is envisioned that we will be able to develop a virtual integrated model-based representation of a physical product, allow the simulation of the product in a real setting in a dynamic fashion, and demonstrate closed loops between the virtual and physical space. Challenges for this include developing an accurate model that precisely reflects the physical twin’s properties. To improve the models further, a digital twin also requires remodeling based on the changes in the product’s configuration. For predicting failures, detailed blueprints of a product’s failure modes are required. Since the digital twin is a replica of the physical product itself, the requirements, qualification, and certification necessary to determine the flight worthiness of the product are the same for the virtual model as well. The expected outcomes of the effort are real-time monitoring and in-flight service of the product, since the digital twin represents an advanced engineered product. This will enable prolonged product life to deliver capabilities continually.

Any product used in naval aircraft can be considered for the proof of concept demonstration (e.g., propulsion engine, electrical power system, fuel system, avionics, air vehicle, auxiliary support equipment, electronic warfare system, human-machine interface).

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. 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: Design and develop a concept to create a digital twin of a product to show its present state using a model. Develop digital twin processes in the product life cycle – design stage to the field use, maintain and sustain in the real-world case. For validation, demonstrate the closed loop that would exist between physical and virtual space. Apply modeling, simulation, and analysis as necessary. Phase I will include prototype plans for Phase II.

PHASE II: Develop a prototype product (a high-fidelity model) by integrating the physical asset to the digital twin and demonstrate the closed loop between physical - virtual - physical space. Demonstrate the

applicability of readiness and sustainment influencing factors such as condition-based maintenance, foreign object detection, predictive maintenance, and flight safety with quantifiable metrics. Quantify the cost benefits, such as reduction in the operation cost and total lifecycle cost, as applicable. Demonstrate the applicability of “what-if” scenarios tested against factors such as product performance management, manufacturing processes, and Navy-unique harsh environmental operating conditions. Demonstrate the scalability of the digital technology to multiple products of an aircraft. Work in Phase II may become classified. Please see note in the Description section.

PHASE III DUAL USE APPLICATIONS: Develop robust architecture, showing the linkage between connectivity and services. Demonstrate the integration of the product into naval aircraft and perform final testing. Successfully transition, implement, and insert the technology for warfighter benefits. Develop mobile application solutions as applicable.

Aerospace industry, Manufacturing, Automobile sectors will benefit from the digital twin technology. The successful demonstration of the digital twin of the product that is operationalized will enable the applicability of the approach to any product/process/service industry to achieve cost benefits.

REFERENCES:

1. “Industry 4.0 and the Digital Twin: Manufacturing Meets Its Match.” Deloitte University Press, 2017. <https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/cip/deloitte-cn-cip-industry-4-0-digital-twin-technology-en-171215.pdf>
2. Grieves, M. & Vickers, J. “Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems (Excerpt).” Springer, 2017. <https://research.fit.edu/media/site-specific/researchfit.edu/camid/documents/Origin-and-Types-of-the-Digital-Twin.pdf>
3. Tao, F., Zhang, M. & Nee, A. “Digital Twin Driven Smart Manufacturing.” Elsevier, 2019. <https://www.sciencedirect.com/book/9780128176306/digital-twin-driven-smart-manufacturing>

KEYWORDS: Digital Double, Artificial Intelligence, Machine Learning, Data Strategy, Architecture, Internet of Things, Cloud, Digital Twin

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

TECHNOLOGY AREA(S): Air Platform, Information Systems

OBJECTIVE: Develop a stable operating system architecture based upon open-source software (OSS) that reduces/eliminates dependence on Microsoft Windows. In comparison to Microsoft Windows 10, OSS operating system architecture should require fewer system resources, reduce software licensing and sustainment costs, reduce the overall Department of Defense (DOD) Information Assurance Vulnerability Alert (IAVA) patch cadence, increase performance, and integrate a robust cybersecurity posture requiring less frequent security updates and reduced typical patch file sizes than Microsoft Windows.

DESCRIPTION: Currently, Portable Electronic Maintenance Aids (PEMAs) employ the Microsoft Operating System (OS) as the host OS. With the transition to Windows 10, Microsoft has migrated to “Windows as a service”. Windows 10 currently requires 20 gigabytes (GB) for a clean install. In addition to an ever-expanding footprint, the OS requires continual patching, with patch sizes often exceeding 1 GB. Each patch cycle requires a vigorous level of testing to ensure that the applications installed on the PEMA function in accordance with mission requirements. Windows license activation requirements present an additional level of complexity for systems that must function in austere environments that include both network connected and standalone/closed-loop configurations. Microsoft Windows activation requires a Key Management Service for connected systems and a soft token for disconnected systems.

The PEMA environment includes network bandwidth restrictions inherited from the host site networks: Integrated Shipboard Network System (ISNS), Consolidated Afloat Network Enterprise Services (CANES), Navy Marine Corps Intranet (NMCI), OCONUS Navy Enterprise Network (ONE NET), or Marine Corps Enterprise Network (MCEN). A significant portion of the PEMA footprint consists of standalone/closed-loop configured systems that do not connect to enterprise network. For standalone/closed-loop configured systems, the squadron Central Technical Publication Librarian must download patches from an enterprise network connected system and sneaker-net patches to the PEMA via DVD or USB hard drives. Whether patches come directly from a PEMA connected to the host-site enterprise network or sneaker-net via DVD/USB hard drive, the patches are first downloaded from an enterprise network. Occasionally patches are too large to transfer over slow/intermittent network connections and encrypted media has to be mailed to the squadron, where especially in the shipboard environment, network bandwidth is at a premium. A software architecture that results in a reduction in typical OS patch file size and patch frequency is a win for the warfighter.

The PEMA Support Equipment environment consists of various Type/Model/Series (T/M/S) specific aircraft and each T/M/S specific aircraft typically includes unique, T/M/S-specific applications. The overarching goal for PEMA is to deliver a single device, to Fleet maintainers, that provide access to technical publications and related Support Equipment applications. Considering the disparate applications required by the various T/M/S aircraft represented within the Support Equipment community, an approach that requires native installation of T/M/S specific application is neither sustainable nor supportable. In order to provide a long-term, supportable and sustainable solution that addresses the Support Equipment fleet maintainer mission on one device, the PEMA architecture must support containerized applications. By employing containerized applications, the process of patching and updating the PEMA underlying software OS architecture is streamlined because patches to the underlying OS do not affect the containerized applications. Employing containerized applications significantly reduces the amount of testing required to ensure T/M/S unique applications function according to mission requirements post patch, as the OS patch does not affect containerized applications.

The overarching requirements are to identify and confirm the viability of an OS architecture alternative to Microsoft Windows that:

- Reduces the frequency and volume (relative to Microsoft Windows 10 OS) of ongoing software vulnerabilities and related requirements for software patch updates as identified and represented by the DoD Information Assurance Vulnerability Management (IAVM) process.
- Results in a reduction in typical file size requirements for OS patches (relative to Microsoft Windows 10) in order to lower network bandwidth requirements.
- Natively supports preboot CAC authentication, and full disk data-at-rest encryption including removable media encryption (without the employment of a third party commercial solution). Note: Data-at-rest encryption must meet DoD Risk Management Framework (RMF) [Ref 4] Controls: SC-28.1 Protection Of Information At Rest and applicable DISA Security Technical Implementation Guides (STIGs) [Ref 5] that include Control Correlation Identifier (CCI) 001199; SC-28(1).3 and SC-28(1).4 Cryptographic Protection and applicable DISA STIGs that include CCIs 002475 and 002476.
- Natively supports two-factor authentication in both network connected and standalone/closed-loop environments. Note: The two factor authentication must meet DoD Risk Management Framework (RMF) [Ref 4] Controls: IA-5(2) PKI-Based Authentication, IA-5(11) Hardware Token-Based Authentication, IA-6 Authenticator Feedback, IA-7 Cryptographic Module Authentication.
- Delivers OS license activation execution that commonly supports connected and standalone environments or does not require license activation.
- Demonstrates compliance with DoD Memorandum “Clarifying Guidance Regarding Open Source Software (OSS)”, dated 16 October, 2009 as well as guidelines from Navy DON CIO Memorandum “DEPARTMENT OF THE NAVY OPEN SOURCE SOFTWARE GUIDANCE” (5 JUN 2007).
- Demonstrates secure file transfer and validation, secure collaboration services, and web browser functionality.
- Supports display of PDF documents,
- Supports live operation in RAM (Secure Live Media),
- Enables hosting and execution of containerized applications,
- Supports Squashed File System high speed compression capabilities.
- Reduces costs related to software licensing relative to the Microsoft Windows Environment.

The OSS operating system should function on a ruggedized, clamshell form factor, 2-in-1 touchscreen/ keyboard configuration such as the Panasonic Toughbook currently employed as the PEMA hardware baseline. Ensure that the Open Source operating system architecture supports application containerization technology [Refs 6 and 7]. Provide an analysis of the potential for reducing the supportability and sustainability footprint with regard to patching. In comparison to Windows 10, describe the estimated benefit relative to:

1. Time and effort involved in patching applicable vulnerabilities on a monthly basis.
2. Typical file size for applicable patches (Identify if there is a patch file size typically smaller for the OSS operating system than Windows 10).
3. Relative frequency of required patching.

The analysis must provide an assessment of the ongoing requirements for patching and updating the system in comparison to the Microsoft Windows 10 environment and contrast the level of effort and risk relative to patching in the Windows environment versus the prototype-operating environment. The analysis must address system performance impacts for live operation in RAM.

PHASE I: Design and determine the technical feasibility of developing an OSS architecture OS that meets the guidelines established in References 8 and 9. With regard to supporting containerized applications identify if there is a significant difference in level-of-effort between the OSS operating system architecture and Windows 10. Provide an assessment of the technical feasibility of the OSS operating system architecture to support the capability requirements discussed in the Description section of this topic. Describe expected lifecycle support costs and tasking related to maintaining compliance with DoD and Navy Open Source Software guidelines identified in the Description. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and demonstrate a prototype 64-bit software architecture, including boot loader, kernel, and operating system to prove open-source concept meeting all requirements provided in the Description.

PHASE III DUAL USE APPLICATIONS: Demonstrate the ability to support containerized applications as discussed in the Description section of this topic. Demonstrate a process for updating a containerized application and the ability to save data from the containerized application to a USB hard drive. Provide design and related support and sustainment documentation. Transition developed technology to the PEMA program of record and field as the core software image which will serve as a potential baseline for all TMS programs to transition unique Windows dependent applications to open-source architectures. Support Risk Reduction Testing, Operational Testing, potential procurement, and pilot fielding to a squadron determined by the PEMA program. Support transition of unique TMS PEMA solutions to operate within this open-source architecture.

Technology development would benefit commercial applications supporting austere environments that require maintenance applications hosted on a ruggedized platform. Success would demonstrate how private companies can employ OSS to reduce costs related to software licensing as well as reduce costs related to ongoing requirements to maintain a strong cybersecurity posture throughout the lifecycle of a system by moving from a Microsoft Windows platform to an OSS platform. This same open source approach could be leveraged to meet other peculiar support equipment requirements in commercial and private sector environments such as commercial aircraft maintenance.

REFERENCES:

1. Economides, N. and Katsamakos, E. "Linux vs. Windows: A Comparison of Application and Platform Innovation Incentives for Open Source and Proprietary Software Platforms." The Economics of Open Source Software Development, Elsevier B.V., 2006.
http://www.stern.nyu.edu/networks/Linux_vs_Windows.pdf
2. Hoepman, J and Jacobs, B. "Software Security Through Open Source." Institute for Computing and Information Sciences, Radboud University, the Netherlands, April 2005.
<https://www.cs.ru.nl/~jhh/publications/oss-acm.pdf>
3. Scarfone, Karen, Jansen, Wayne, and Tracy, Miles. "National Institute of Standards Technology (NIST) Special Publication 800-123, Guide to General Server Security – Recommendations of NIST." July 2008. <http://csrc.nist.gov/publications/nistpubs/800-123/SP800-123.pdf>
4. "DoD Risk Management Framework (RMF) Controls: SC-28.1 Protection Of Information At Rest, IA-5(2) PKI-Based Authentication, IA-5(11) Hardware Token-Based Authentication, IA-6 Authenticator Feedback, IA-7 Cryptographic Module Authentication." <https://nvd.nist.gov/800-53/Rev4/control/IA-5>, <https://nvd.nist.gov/800-53/Rev4/control/IA-6>, <https://nvd.nist.gov/800-53/Rev4/control/IA-7>, <https://nvd.nist.gov/800-53/Rev4/control/IA-SC-28>

5. DISA Security Technical Implementation Guides (STIGs) Control Correlation Identifier (CCIs): 001199, 002475, 002476. <https://public.cyber.mil/stigs/>

6. Chandramouli, Ramaswamy. “National Institute of Standards and Technology (NIST) Interagency Report (IR) NISTIR 8176: Security Assurance Requirements for Linux Application Container Deployments.” <https://nvlpubs.nist.gov/nistpubs/ir/2017/NIST.IR.8176.pdf>

7. Souppaya, Murugiah, Morello, John and Scarfone, Karen. “NIST Special Publication 800-190 Application Container Security Guide.” <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-190.pdf>

8. “DoD Memorandum: Clarifying Guidance Regarding Open Source Software (OSS).” 16 October, 2009. <https://dodcio.defense.gov/Portals/0/Documents/FOSS/2009OSS.pdf>

9. “Navy Memorandum DEPARTMENT OF THE NAVY OPEN SOURCE SOFTWARE GUIDANCE (5 JUN 2007). <https://www.doncio.navy.mil/FileHandler.ashx?id=261>

10. DoD Frequently Asked Question (FAQ) regarding Open Source Software (OSS). <https://dodcio.defense.gov/Open-Source-Software-FAQ>

KEYWORDS: Cyber Security, Windows as a Service, IAVM, Open Source Software, Open Source Architecture, Application Container, OSS, Operating System, OS

N202-107

TITLE: Radio Communication with Hypersonic Aerial Vehicle

RT&L FOCUS AREA(S): Hypersonics, Network Command, Control and Communications;
TECHNOLOGY AREA(S): 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: Develop an effective radio frequency communication system solution for communicating through the plasma sheath surrounding a hypersonic aerial vehicle.

DESCRIPTION: When a vehicle is traveling at hypersonic speed through the atmosphere, a plasma sheath envelops the aerial vehicle because of the ionization and dissociation of the atmosphere surrounding the vehicle [Refs 1-3]. The plasma sheath prevents radio communication, telemetry, and Global Positioning System (GPS) signal reception for navigation [Ref 4].

This radio “blackout” period poses a serious challenge that hinders the use of hypersonic aerial vehicles for future naval applications. Development of an appropriate mitigation method to allow uninterrupted aerial vehicle to control station and control station to vehicle communications through the plasma sheath during the entire hypersonic flight is required.

Develop and demonstrate an effective blackout mitigation solution that enables continuous communication between a stationary or mobile platform and a hypersonic vehicle during hypersonic flight. Many mitigation techniques have been proposed, including but not limited to, aerodynamic shaping, magnetic windows, and liquid injection. Any innovative solution capable of eliminating any radio frequency communication disruptions due to the plasma sheath [Ref 4] will be considered.

PHASE I: Develop concepts for communication directly through the plasma sheath of a hypersonic aerial vehicle in the frequency band between 1.1 to 5.6 GHz for error-free GPS and radio communication for a separation distance up to 20,000 km. Perform modeling and simulation of the proposed concepts in the hypersonic environment to validate their feasibility. Complete design tradeoffs to predict the performance, size, weight, and power requirement of the most promising design. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a hardware prototype based on the Phase I design. Demonstrate the prototype’s radio frequency communication capability and characterize its communication performance in a terrestrial plasma chamber to establish proof of concept.

PHASE III DUAL USE APPLICATIONS: Fully develop and transition the radio frequency communication system based on the final design from Phase II for Naval applications in the areas of reliable and error-free radio communication with hypersonic aerial vehicles.

The commercial sector would benefit from this research and development in the area of radio communication with hypersonic re-entry space vehicles.

REFERENCES:

1. Chadwick, K.M., Boyer, D.W. and Andre, S.S. "Plasma and Flowfield Induced Effects on Hypervelocity Reentry Vehicles for L-Band Irradiation at Near Broadside Aspect Angles." 27th AIAA Plasmadynamics and Lasers Conference, New Orleans, LA, June 1996.
<https://arc.aiaa.org/doi/10.2514/6.1996-2322>
2. Norris, G. "Plasma Puzzle: Radio Frequency-Blocking Sheath Presents a Hurdle to Hypersonic Flight." Aviation Week & Space Technology, March 2009, p. 58.
3. Blottner, F.G. "Viscous Shock Layer at the Stagnation Point with Nonequilibrium Air Chemistry." AIAA Journal, vol. 7, no. 12, December 1969, pp. 2281-2288.
<https://arc.aiaa.org/doi/abs/10.2514/3.5528?journalCode=aiaaj>
4. Hartunian, R.A. et al. "Implication and Mitigation of Radio Frequency Blackout during Reentry of Reusable Launch Vehicles." AIAA Atmospheric Flight Mechanics Conference, Hilton Head, South Carolina, Aug 20-23, 2007

KEYWORDS: Radio Frequency, Communication, Plasma, Hypersonic, Black-Out, GPS

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

TECHNOLOGY AREA(S): Air Platform, 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 software tool to optimize the signal processing chain across various sensors and systems, e.g., radar, electronic warfare (EW), electro-optical/infrared (EO/IR), and communications, that consists of functional models that can be assembled to produce an integrated network model used to predict overall detection/classification, power, and throughput performance to make design trade-off decisions.

DESCRIPTION: Conventional computing architectures are running up against a quantum limit in terms of transistor size and efficiency, sometimes referred to as the end of Moore's Law. To regain our competitive edge, we need to find a way around this limit. This is especially relevant for small size, weight, and power (SWaP)-constrained platforms. For these systems, scaling Von Neumann computing becomes prohibitively expensive in terms of power and/or SWaP.

Biologically inspired neural networks provide the basis for modern signal processing and classification algorithms. Implementation of these algorithms on conventional computing hardware requires significant compromises in efficiency and latency due to fundamental design differences. A new class of hardware is emerging that more closely resembles the biological neuron model, also known as a spiking neuron model; mathematically describing the systems found in nature and may solve some of these limitations and bottlenecks. Recent work has demonstrated performance gains using these new hardware architectures and have shown equivalence to converge on a solution with the same accuracy [Ref 1].

The most promising of the new class are based on Spiking Neural Networks (SNN) and analog Processing in Memory (PiM) where information is spatially and temporally encoded onto the network. It can be shown that a simple spiking network can reproduce the complex behavior found in the neural cortex with significant reduction in complexity and power requirements [Ref 2]. Fundamentally, there should be no difference in algorithms based on neural networks. In fact, they can easily be transferred between hardware architectures [Ref 4]. Performance gains and the relative ease of transitioning current algorithms over to the new hardware motivates consideration of this SBIR topic.

Hardware based on SNN is currently under development at various stages of maturity. Two prominent examples are the IBM True North and the Intel Loihi chips. The IBM approach uses conventional Complementary Metal-Oxide Semiconductor (CMOS) technology and the Intel approach uses a less mature memristor architecture. Estimated efficiency performance increase is greater than 3 orders of magnitude better than state-of-the-art graphics processing units (GPU) or field-programmable gate arrays (FPGA). More advanced architectures based on an all optical or photonic-based SNN show even more promise. Nano-Photonic-based systems are estimated to achieve 6 orders of magnitude increase in efficiency and computational density, approaching the performance of a human neural cortex. Modeling

these systems to make design and acquisition decisions is of great interest and importance. Validating these performance estimates and providing a modeling tool is the basis for this SBIR topic.

The primary goal of this effort is to create a software tool that captures the non-linear physics of these SNNs, and possibly other neuromorphic and related low-SWaP architectures, as well as functionally model their behavior. It is recommended to use open source languages, software, and hardware when possible. A similar approach [Ref 6] should be considered as a starting point, with the ultimate goal of producing a viable and flexible product for capturing, modeling, and understanding the behaviors of a composite system constructed to employ these adaptive learning systems, including all systems ranging from CMOS to photonics. Additionally, the model should be able to take an algorithm developed on a conventional neural network framework like Caffe, PyTorch, TensorFlow, etc. and run it through the functional model to predict performance criteria like latency and throughput. The secondary goal is to build up a network framework to model multi-step processing chains. For example, a hypothetical processing chain for a communications system might be filter, in-phase quadrature (IQ) demodulation, frequency decomposition, symbol detection, interference mitigation, filter, and decryption.

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. 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: Design and develop the modeling approach and demonstrate feasibility to capture the relevant physics and computational complexity. Demonstrate a functional model of a SNN. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Validate the functional model using test cases from literature. Model validation with hardware is strongly encouraged, however, due to the limited availability of hardware this is not a requirement. The model will need to contain a network framework for various processing steps across multiple sensor areas using lower level functional models. Priorities sensor/functional areas are EW, radar, communications, and EO/IR.

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

PHASE III DUAL USE APPLICATIONS: Refine algorithms and test with hardware. Validate models with data provided by Naval Air Warfare Center (NAWC) Aircraft Division (AD)/Weapons Division (WD). Transition model to the warfare centers. Development of documentation, training manuals, and software maintenance may be required.

Heavy commercial investments in machine learning and artificial intelligence will likely continue for the foreseeable future. Adoption of hardware that can deliver on orders of magnitude in SWaP performance for intelligent mobile machine applications is estimated to be worth 10^9 - 10^{12} global dollars annually.) Provide the software tools needed to optimize the algorithms and hardware integration. This effort would be a significant contribution to this requirement. Industries that would benefit from successful technology development include automotive (self-driving vehicles), personal robots, and a variety of intelligent sensors.

REFERENCES:

1. Ambrogio, S., Narayanan, P., Tsai, H., Shelby, R.M., Boybat, I., Nolfo, C.D., Sidler, S., Giordano, M., Bodini, M., Farinha, N.C., Killeen, B., Cheng, C., Jaoudi, Y. & Burr, G.W. "Equivalent-accuracy accelerated neural-network training using analogue memory." *Nature*, 558, 2018, pp. 60-67
DOI:10.1038/s41586-018-0180-5
2. Izhikevich, E.M. "Simple model of spiking neurons." *IEEE Transactions on Neural Networks*, Volume: 14, Issue: 6, 2003. <https://ieeexplore.ieee.org/document/1257420>
3. Diehl, P. U., Zarella, G., Cassidy, A., Pedroni, B. U. & Neftci, E. "Conversion of artificial recurrent neural networks to spiking neural networks for low-power neuromorphic hardware." *ArXiv:1601.04187 [cs:NE]*, 2016. <https://arxiv.org/pdf/1601.04187.pdf>
4. Esser, S.K., Merolla, P., Arthur, J.V., Cassidy, A.S., Appuswamy, R., Andreopoulos, A., Berg, D.J., McKinstry, J.L., Melano, T., Barch, D., Nolfo, C.D., Datta, P., Amir, A., Taba, B., Flickner, M. & Modha, D.S. "Convolutional networks for fast, energy-efficient neuromorphic computing." *Proceedings of the National Academy of Sciences of the United States of America*, 113 41, pp. 11441-11446.
<https://arxiv.org/pdf/1603.08270.pdf>
5. "National Defense Strategy 2018." United States Congress.
<https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>
6. Rajendran, B., Sebastian, A., Schmuker, M., Srinivasa, N. & Eleftheriou, E. "Low-Power Neuromorphic Hardware for Signal Processing Applications." <https://arxiv.org/pdf/1901.03690.pdf>
7. Wolfe, N., Plagge, M., Carothers, C. D., Mubarak M. and Ross, R. B. "Evaluating the Impact of Spiking Neural Network Traffic on Extreme-Scale Hybrid Systems." 2018 IEEE/ACM Performance Modeling, Benchmarking and Simulation of High Performance Computer Systems (PMBS), Dallas, TX, USA, 2018, pp. 108-120. doi: 10.1109/PMBS.2018.8641660

KEYWORDS: Spiking Neural Network, Neuromorphic Computing, Modeling, Convolution Neural Network, Analog Memory, Processing in Memory

N202-109

TITLE: Launch System for Group 3-5 Unmanned Aerial Vehicles for Land- and Sea-Based Operations

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

TECHNOLOGY AREA(S): Air Platform, Ground Sea

OBJECTIVE: Develop a reconfigurable Unmanned Aerial Vehicle (UAV) Launch System to add to an Expeditionary Sea Base (ESB) Navy Ship as a self-contained mission-driven kit. (The launch system is intended to enable UAVs such as the XQ-58A Valkyrie [Ref 5] to operate from ESBs.)

DESCRIPTION: The Navy needs to operate Group 3-5 [Ref 3] fixed wing UAVs from ships other than an aircraft carrier - a capability gap that, if overcome, would significantly increase lethality, project force, and increase the range of Intelligence/Surveillance/Reconnaissance (ISR). The UAV Launch System should be comprised of a launch technology capable of accelerating a fixed-wing, jet-powered UAV, with a wingspan of 30 feet and weight up to 6,000 pounds, up to 150 knots-indicated air speed (KIAS). The launch technology must reside, to the maximum extent possible, within the hull of the ESB. Coordination with NAVSEA/NAVAIR will be critical to understanding the most current available space(s) aboard ship, as well as any weight/power restrictions on the new launch system.

The Launch System must be designed to not interfere with top-side flight deck operations of the ESB, accommodate Group 3-5 UAVs with or without landing gear, and be reconfigurable such that it can conduct both shipboard launches (operationally aboard an ESB) and ground-based launches (during demonstration testing prior to installation aboard any ship). Should features of the Launch System exceed available space inboard, 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 launch 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.

The UAV Launch System must be simple enough in design to allow for sustained operations at high sortie generation rates (i.e., rapid and repeated launchings of multiple UAVs, with a goal of a UAV launch every two minutes), with high reliability and little maintenance down time for 24 hour/7 day surge periods. Details of the Launch System kit need to include all the necessary subsystems and interface components required to permit their rapid installation aboard the ESB. Control and operation of the Launch System will be from the hangar bay of the ESB. Adhere to all applicable environmental standards of the latest version of MIL-STD-810 [Ref 4], such as shock, vibration, electromagnetic interference/emission, etc.

Work must be collaborative with NAVAIR and NAVSEA, to identify air-ship integration requirements, constraints, and compatibility between Group 3-5 UAVs and ESB.

PHASE I: Develop a proof-of-concept design to meet the Objective and details provided in the Description. Use a computer simulation tool, such as Solid Works, to provide analyses of the design features and projected operation of the Launch System and its major components. Provide schedule, technical challenges, and estimated ship alt costs. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop the design from Phase I further and provide an additional detailed digital analyses of all components of the proposed Launch System, including fit checks aboard an ESB (if appropriate, structural/mechanical/functional details on any sponson utilized in the design) and functional/operational simulations. Demonstrate a 1/8 scale prototype of the Launch System, with adequate representation of the

geometries and functioning major subsystems. Using a 100-pound UAV provided by the Government, conduct a ground demonstration of the prototype Launch System and report results.

PHASE III DUAL USE APPLICATIONS: Perform any final testing and transition complete Launch System kit(s) to Navy, Marine Corps, Air Force, and possibly some combatant commands (COCOMS) for full-scale ground testing of the technology involving Group 3-5 UAVs, and ultimate outfitting onto an ESB.

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 such UAV launch 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 Staff. "EMALS/ AAG: Electro-Magnetic Launch & Recovery for Carriers." March 2019. <https://www.defenseindustrydaily.com/emals-electro-magnetic-launch-for-carriers-05220/>
3. "Classification of the Unmanned Aerial Systems." Penn State Department of Geography, College of Earth and Mineral Sciences. <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/
5. Staff Writer. "Kratos XQ-58 Valkyrie (XQ-222)" Unmanned Combat Aerial Vehicle (UCAV). Military Factory, March 2019. https://www.militaryfactory.com/aircraft/detail.asp?aircraft_id=1755

KEYWORDS: Unmanned Aerial Vehicle, UAV, Unmanned Aerial System, UAS, Expeditionary Sea Base, ESB, XQ-58A, Sponson, Group 3-5 UAV

N202-110

TITLE: Miniature 360-degree Multispectral/Hyperspectral Staring Imaging System

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

TECHNOLOGY AREA(S): Battlespace

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 miniature 360-degree Multispectral/Hyperspectral staring imaging system with discriminate classification capabilities for use on Navy manned and unmanned aircraft.

DESCRIPTION: U.S. Navy manned and unmanned aircraft platforms have a need for 4p steradian coverage for situational awareness while performing their required missions. In addition, airborne surveillance systems need to meet multiple mission requirements for automatic detection, track, and identification of a variety of objects to include aircraft, missiles, and obstructions hazardous to flight. There is a need for reduced size multispectral/hyperspectral imaging to provide a capability to conduct search, detection, classification, localization, tracking, and attack of surface ships and surfaced submarines in both clear and adverse weather, and in both the littoral and blue water environments. Small target examples are anti-aircraft missiles, Tier 1 Unmanned Aerial Systems (UAS), patrol craft, and submarines. Systems that are integrated onto airborne platforms need to meet stringent requirements for size, weight, power, and cost (SWaP-C); as well as aircraft requirements for environmental conditions such as vibration, shock, heat, altitude, etc. These requirements vary from aircraft to aircraft, but hold a common theme of reduced SWaP-C sensors to meet a number of aircraft requirements. The initial platform requirements will include the P-8A and MQ-4C platforms. The P-8A and MQ-4C will provide air defense capabilities to defend, identify, classify and track air targets and threats to the aircraft. In addition, the aircraft conducts Search and Rescue (SAR) missions. Current system concepts, such as large pods, are normally single purpose and impact mission performance by excessive SWaP-C that limits on-station time by increased drag counts and negative impacts to fuel consumption.

The multispectral/hyperspectral imaging system should provide 4p steradian coverage. The SWaP should be limited to approximately 100 pounds, total volume of 2 cubic feet, and have less than 500 Watts of input power required. Aircraft power requirements in accordance with MIL-STD-704 and MIL-STD-461 should be taken into consideration. Cost should be less than \$300K per unit as manufactured. Aircraft environmental conditions in accordance with MIL-STD-810 should be taken into consideration. The sensors need to be external to the aircraft and be low drag as to not increase fuel consumption by more than 1%.

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. 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: Develop a concept of a miniature spectral imaging digital system that can automatically search for air, surface targets and launch transients in littoral and blue water operations. The system should be able to automatically detect and classify multiple targets and provide threat warnings for 4p steradian coverage. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Further refine the architecture and algorithms developed in Phase I and develop a working prototype to include high-level surveillance requirements for automatic detection, tracking, and identification over 4p steradians of aircraft, missiles and flight obstructions, software development, initial system testing, and a lab or ground-based demonstration.

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

PHASE III DUAL USE APPLICATIONS: Perform final testing and transition the developed technology to appropriate Navy manned and unmanned aircraft platforms. Hyperspectral sensing has a multitude of application in commercial remote sensing. These include commercial aircraft and ground vehicle surveillance for collision avoidance, manufacturing safety systems, and inspection and surveillance systems.

REFERENCES:

1. Stein, D., Schoonmaker, J., and Coolbaugh, E. "Hyperspectral Imaging for Intelligence, Surveillance, and Reconnaissance." SSC San Diego, Aug 2001. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a434124.pdf>
2. Anderson, R.C., Malila, W., Maxwell, R. & Reed, L.K. "Military Utility of Multispectral and Hyperspectral Sensors." Infrared Information Analysis Center Environmental Research Institute of Michigan, November 1994. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a325724.pdf>
3. Wang, Z., Nasrabadi, N.M. & Huang, T.S. "Discriminative and compact dictionary design for Hyperspectral Image classification using learning VQ framework." 2013 IEEE International Conference on Acoustics, Speech and Signal Processing, pp. 3427-3431. <https://ieeexplore.ieee.org/document/6638294>
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/
5. "MIL-STD-704F, DEPARTMENT OF DEFENSE INTERFACE STANDARD: AIRCRAFT ELECTRIC POWER CHARACTERISTICS (12 MAR 2004)." http://everyspec.com/MIL-STD/MIL-STD-0700-0799/MIL-STD-704F_1083/
6. "MIL-STD-461G, DEPARTMENT OF DEFENSE INTERFACE STANDARD: REQUIREMENTS FOR THE CONTROL OF ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF SUBSYSTEMS AND EQUIPMENT (11-DEC-2015)." http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-461G_53571/

KEYWORDS: Multispectral, Hyperspectral, Remote Sensing, Optics, Imaging, Surveillance

N202-111

TITLE: Desktop Tactics Trainer for Maritime Patrol Aircraft

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

TECHNOLOGY AREA(S): Air Platform, 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 desktop trainer with a low-cost, computer-based, simulated environment where students can practice tactics learned in advance of discussions, simulator events, and flight events.

DESCRIPTION: Fleet Naval Flight Officers (NFOs) in the Maritime Patrol community are trained to: 1) conduct anti-submarine warfare first, 2) conduct intelligence, surveillance, and reconnaissance always, and 3) conduct anti-surface warfare, if needed. They use the multi-mission aircraft platform to accomplish these missions. The aircrew consist of multiple personnel (both enlisted and officers) operating a multitude of sensors. Using their training, and the complex yet effective aircraft, they are tasked with finding and tracking submarines and ships in the world's oceans.

Current students work through a syllabus comprised of verbal knowledge discussion and quizzes, simulators, and flight events. Currently fleet students (upgraders) do not have any tool that allows them to try-out and practice learned tactics in a simulated environment without scheduling highly limited and valuable time in a multi-million-dollar simulator. This SBIR topic seeks to fill the gap between learning tactics from a book, and utilizing those tactics in a simulator event by providing a low-cost, computer based, simulated environment where students can try out what they learned and practice tactics in advance of discussions, as well as simulator and flight events. Low cost should be considered as a solution that is capable of running on a typical mid-range Windows computer (laptop or desktop), typical of what most training centers have organic to their building. By providing an additional "learn on your own" simulation tool, students can increase their knowledgebase before an event, and decrease the likelihood of event failure, maximizing the value of expensive crew simulator events, both in effectiveness and efficiency. The ultimate result of a basic computer-based simulation tool will be trainees who are more highly qualified at the end of their training, making them more ready and able to perform tasks.

The job is a difficult one and although the crew has a capable aircraft, they need to be proficient in their roles making the most use of the maritime platform. Although crewmembers conduct training flights and their qualifications primarily in live flights, they maintain a strong reliance on various training devices, as real ships and submarines are typically not available to train maritime aircraft crews. Additionally, when given real surface and subsurface platforms to train with, they are U.S. or allied friendly force units. Training against real-world adversaries would provide a higher fidelity of learning.

A computer-based tactics trainer is a cost-efficient and effective way to provide hands on tactics training on demand to NFOs in training, or as a means to maintain knowledge, skills, and abilities overtime. The idea of the computer-based tactics trainer was a Fleet born idea, specifically to address the eagerness of crewmembers to apply their classroom training in a practical way, and on their own time, rather than waiting for the next scheduled part-task trainer (PTT) or weapon tactics trainer (WTT) simulator event. The computer-based tactics trainer would allow them to load up a myriad of relevant pre-built scenarios,

or create their own, to practice the tactical and decision-making aspect of prosecuting subsurface (or surface) entities. At first, this capability would look to replicate the Tactical Coordinator's (TACCOs) role, as mission commander. These NFOs receive inputs from the various sensor feeds and fellow crewmembers and compile the information to formulate a plan. The tactics trainer would then let the TACCO in training implement different tactics against the same target and see how each might turn out. Due to the tactical nature of the trainer, the trainee will need to see realistic outcomes and information from his or her inputs and actions. Through this, trainees that would like to practice their lessons to mastery, or close to it, can sit down at a standard computer, likely within the training center, load the computer-based tactics trainer, and run through scenario after scenario when they have time to do so. There are likely a few ways to accomplish the same goal when conducting a mission and the tactics trainer is the gateway to open those possibilities to a creative TACCO. The trainee can then try to implement their more effective tactics, techniques, and procedures once he or she gets to the high-fidelity simulator events with the rest of a crew. The tactics trainer can build confidence in new trainees, maintain Knowledge, Skills and Abilities (KSAs) of current crew members, and enable NFOs to use their valuable full simulator time in the most effective way.

Ensure Risk Management Framework (RMF) and Information Assurance (IA) guidelines [Ref 5] are considered during early software development to ensure future compliance.

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. 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: Design and develop an innovative approach for a computer-based tactical trainer in the maritime patrol domain, or a similar domain for feasibility demonstration. All initial demonstrations will use publicly available data during Phase I. Demonstrate the feasibility of the proposed approach to be further developed in Phase II. Consider RMF and IA guidelines [Ref 5] during early software development to ensure future compliance. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Based upon the proposed solution in Phase I, develop and demonstrate a prototype using the maritime patrol domain, specifically targeting the role of the Tactical Coordinator. Several realistic scenarios will be developed, including a creative/sandbox mode where the trainee can design his or her own scenario to then engage with. Fleet stakeholders will assist with the identification of desired scenarios, first at the Unclassified level and later at the Classified level. A form of automated performance measurement will be included and pulled from fleet doctrine in order to inform trainees how they are performing based on the standard qualifications. Demonstrate the working prototype computer-based tactical trainer. Ensure that RMF guidelines to support IA compliance are met throughout software development.

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

PHASE III DUAL USE APPLICATIONS: Further develop and refine the system to suit the needs of end users based on Phase II feedback and testing. Develop additional scenarios based on fleet needs and

finalize the sandbox/creative mode. Demonstrate the validity of the software for transition purposes defined by the end-user Subject Matter Experts in the maritime patrol community. Plan and execute final testing of the trainer to Fleet stakeholders. Transition the capability to Fleet stakeholders within their training environment. The final capability will require RMF, information assurance, and cybersecurity compliance with all relevant regulations and guidelines.

The architecture and design of the training tool, especially creative/sandbox mode, can be useful in professional industry and academic environments where planning and process implementation is warranted during lower fidelity training. This tool could be useful in dynamic environments such as aviation or maritime domains where the nature of tasks changes frequently.

REFERENCES:

1. Nan, Q. & Liang, M. (2018, March). "SubSafe--A Game-based Training System for Submarine Safety." In 2018 Joint International Advanced Engineering and Technology Research Conference (JIAET 2018). Atlantis Press.
2. Slocombe, G. (2018). "Joint terminal attack controllers." Asia-Pacific Defence Reporter (2002), Volume 44, Issue 2, p. 34.
<https://search.informit.com.au/documentSummary.dn=435184434741982,res=IELBUS,type=pdf>
3. Reweti, S., Gilbey, A. & Jeffrey, L. "Efficacy of low-cost PC-based aviation training devices." Journal of Information Technology Education-Research, Volume 16, 2017, pp. 127-142.
<https://eric.ed.gov/?id=EJ1140175>
4. Freeman, J., Tolland, M., Priest, H., Walwanis, M., Newton, C., Mooney, J. & Bolton, A. "A tactical decision trainer for cross-platform command teams." Interservice/Industry Training, Simulation and Education Conference, 2016. http://jaredfreeman.com/jf_pubs/Freeman-TacticalDecisionTrainer-IITSEC-2016.pdf
5. Risk Management Framework (RMF) Overview: [https://csrc.nist.gov/projects/risk-management/risk-management-framework-\(RMF\)-Overview](https://csrc.nist.gov/projects/risk-management/risk-management-framework-(RMF)-Overview)

KEYWORDS: Training, Interactive, Desktop Trainer, Anti-Submarine Warfare, Tactics Trainer

N202-112

TITLE: Multi-Domain Data Fusion Instructional Strategies and Methods for Pilot Training

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platform, 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: Research and develop training objectives for the multi-domain environment and instructional strategies for manned-unmanned data fusion tactical decision making. Research and develop instructional tools that support defined strategies and methods to increase operator training effectiveness and mission readiness.

DESCRIPTION: Operator reliance on sensor fusion is becoming more prominent as platforms increase reliance on automated technology in next generation platforms. Further, as programs look to extend platform capabilities through off-board, unmanned sensor technology and capabilities, requirements for operator synthesis of data and decision-making based on manned-unmanned collaboration will become an essential part of operations. As these technologies advance, training systems must identify appropriate instructional strategies and training methods to ensure that operators understand the implications of automated technologies. Advanced platforms and systems, including Joint Strike Fighter and Strike Planning and Execution Systems, offer unique use cases facing these challenges. Additionally, interest has been expressed by programs such as Aerial Targets and Multi-Mission Tactical Unmanned Aerial Systems, and for long-term data fusion enhancements based on future system concept of operations for future helicopter platforms.

This SBIR topic seeks to identify unique instructional strategies necessary for supporting manned-unmanned teaming to ensure effective and efficient operator performance. Performance is measured using both automated measures derived from available data sources and observer-based measures. Significant increases from a baseline (pre-implementation of the technology) would constitute acceptable improvement, as well as impacts to expected relevant manned-unmanned teaming factors including communication, trust, and workload. Further, an analysis of crew resource management instructional methods is necessary to identify mechanisms for extending these well-established principles to manned-unmanned teaming environments to ensure training technologies and approaches best address these future requirements. As part of this effort, development and demonstration of a software technology prototype is desired that supports training built upon the instructional strategies and methods defined. The hardware and software must meet the system DoD accreditation and certification requirements to support processing approvals for use through the policy cited in Department of Defense Instruction (DoDI) 8510.01, Risk Management Framework (RMF) for DoD Information Technology (IT) [Ref 1], and comply with appropriate DoDI 8500.01, Cybersecurity [Ref 7]. Finally, research into the effectiveness of the instructional strategies and technologies developed based on these concepts is necessary to determine feasibility prior to transition.

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 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: Research and develop training objectives for the multi-domain environment and instructional strategies for manned-unmanned data fusion tactical decision making. Identify training technology to assist instructors with training and/or technologies to support instructorless training (e.g., scaffolding) that might provide beneficial uses in operational contexts for operator job aids when leveraging manned-unmanned data fusion for tactical decision making. Research and develop recommendations for automation transparency to support operator tactical decision making when leveraging manned-unmanned data fusion technology in multi-domain environments. The Phase I effort will include plans to be developed under Phase II.

PHASE II: Research and develop instructional tools that support defined strategies and methods to increase operator training effectiveness and mission readiness, including both technology to support instructor-led and instructorless training situations. Demonstrate operational utility of the technology for providing operator job aids and adjusting the level of transparency of automated data fusion systems to increase operator performance in manned-unmanned teaming environments. Demonstrate a 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.

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

PHASE III DUAL USE APPLICATIONS: Integrate instructional tools within a training system environment and/or transition technology via a Program Office to an operational system to provide operator job aids or enhancements to operator interfaces to increase performance. Attain Risk Management Framework certification for an authority to operate within operational/training systems. Data fusion technologies are increasingly beneficial in the commercial sector with the influx of data analytics and advances in technology. Industries that employ commercial logistics tracking, trucking, and commercial aviation (due to the likely increase of commercial drones) may all benefit from the SBIR-developed technology solutions.

REFERENCES:

1. "Risk Management Framework (RMF) for DoD Information Technology (IT)." Department of Defense, Washington D.C.: Executive Services Directorate, 2014. https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/851001_2014.pdf
2. BAI Information Security Consulting & Training. (2020). BAI: Information Security RMF Resource Center. Retrieved from Risk Management Framework. [https://csrc.nist.gov/projects/risk-management/risk-management-framework-\(RMF\)-Overview](https://csrc.nist.gov/projects/risk-management/risk-management-framework-(RMF)-Overview)
3. Kaelbling, L. P., Littman, M. L. & Moore, A. W. "Reinforcement Learning: A Survey." Journal of Artificial Intelligence Research 4, 1996, pp. 237-285. <https://arxiv.org/pdf/cs/9605103.pdf>

4. Cummings, M. L., Brzezinski, A. S. & Lee, J. D. “The Impact of Intelligent Aiding for Multiple Unmanned Aerial Vehicle Schedule Management.” IEEE Intelligent Systems: Special Issue on Interacting with Autonomy, 2007, pp. 52-59. <https://dspace.mit.edu/handle/1721.1/90287>
5. Salamon, A., Housten, D. & Drewes, P. “Increasing Situational Awareness Through the Use of UXV Teams While Reducing Operator Workload.” Semantic Scholar: Cherry Hill, 2009. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.614.2182&rep=rep1&type=pdf>
6. Breazeal, C., Hoffman, G. & Lockerd, A. “Teaching and Working with Robots as a Collaboration.” AAMAS '04: Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems, 2004. pp. 1030-1037. <https://dl.acm.org/doi/10.5555/1018411.1018871>
7. “Department of Defense Instruction 8500.01, Cybersecurity.” https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/850001_2014.pdf

KEYWORDS: Training, Data Fusion, Sensor Fusion, Manned-unmanned Teaming, Instructional Strategies, Job Aids

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

TECHNOLOGY AREA(S): Air Platform, 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: Design and develop an innovative, automated, low-cost Mid-Body Range Safety Subsystem (MRSS) to meet range safety and platform engineering requirements for flight testing of the Tomahawk Weapons System launched from designated surface ships, submarines, and mobile ground launchers.

DESCRIPTION: The MRSS is an instrumentation package installed in the Tomahawk missile body prior to flight testing. In general, the MRSS provides three basic functions: telemetry, tracking, and flight override/flight terminate. The Tomahawk MRSS is comprised of an antenna, transmitter and a PCM Encoder that collects the missile data and puts it in a format to be transmitted. Currently, tracking is accomplished using a C-band transponder and an antenna. The flight override/flight terminate system will, typically, have an antenna, flight terminate receivers (FTRs), a control decoder (for flight override), and an electronics box that can sense the terminate command from the FTRs and interface with the missile methodology of crashing the missile.

The MRSS is required to meet data collection and range safety requirements. It provides the missile with a communications link with test ranges during flight tests and enables the missile to be tracked, monitored, and controlled or terminated by test range personnel during flight testing. This subsystem is only present during flight and related testing, and is comprised of a Range Safety Electronics Unit (RSEU) and a Tri-Band Antenna. The MRSS provides telemetry (TM) data at a rate of 2.5 megabits per second. The communications include missile instrumentation data, range command and control, flight termination, and position tracking. For submarine launch, selected missile data are stored and retransmitted to allow for missile performance evaluation from intent to launch (ITL) Command through broach. The RSEU sealing design (preventing JP-10 intrusion) satisfies the 60704 JP-10 compatibility requirement on internal RSEU components.

The solution cannot exceed the physical characteristics listed below and must fit in the mid-body section of a Tomahawk missile. Please note that the MRSS Spec and the TT-SRD-98-0058 System Safety Program Plan will be provided to the Phase I performers.

- Physical Characteristics (current MRSS):
 - a. The current MRSS spec (PMA280-1208) does not list a weight nor any other physical and/or dimensional requirements. However, the existing design provides framework for the replacement kit. Any replacement kit will be constrained by the current design's mechanical and electrical requirements/characteristics and interfaces with the missile.
 - b. Power must be self-contained and independent from a Tomahawk missile
 - c. The missile platform contractor will need to rework all center of gravity (CG) calculations based on new MRSS design.

- Transmitting Requirements:
 - a. Transmit missile performance telemetry data and flight termination system status via S-band radio frequency (RF) link.
 - b. Position tracking via C-band transponder.
 - c. Demodulate an ultra-high frequency (UHF) RF link and provide for override command and control of the missile by a designated RF source.
 - d. Provide a discrete signal to the Mission Control Processor (MC I/O) indicating loss-of-tone of Range Safety Carrier.
 - e. Initiate missile flight termination action following receipt of any of the indications below:
 1. Receipt of a COMMAND TERMINATE
 2. Receipt of "Loss-of-tone/Initiate Flight Terminate" (SW 35) signal from the Pyro/Power Control Assembly (PPCA) within the missile Guidance Electronics Unit.
 3. CMA bus voltage drops below the specified low operating voltage for the flight terminate receivers.
 - f. Provide a pre-launch BIT capability to verify presence of adequate flight termination back-up activation power and operation of flight termination receiver/decoders.

- Shock and Vibration: The MRSS environments must meet CMP3900 Rev B, Appendix E. The FTS components must meet RCC-319 [Ref 1]. RCC-319 typically adds 3-6 db to the expected flight levels. The qualification of the FTS is coordinated with the Range Safety Offices (RSOs) of the ranges where the missile is tested.

- Temperature: Temperature, pressure and other environment requirements are specified in PMA280-1208, para. 3.2.5.
 - a. Material: As specified in PMA280-1208, para. 3.3.1.1.
 - b. EMI/EMC/Stress: As specified in PMA280-1208, para. 3.3.2
 - c. HERO: As specified in PMA280-1208, para. 3.3.2.3.
 - d. Built-In-Test (BIT): PMA280-1208 specifies BIT requirements as follow:
 1. Para 3.2.1.1.f : Provide a pre-launch BIT capability to verify presence of adequate flight termination back-up activation power and operation of flight termination receiver/decoders.
 2. Para 3.2.1.1.7: Pre-launch BIT. When powered with pre-launch power, the MRSS system must provide a continuous BIT check until removal of bus power.
 3. As a minimum, the MRSS shall monitor the performance of the following items:
 - Flight termination backup activation power.
 - Dual receiver Automatic Gain Control (AGC) voltages.

(These requirements are only for a pre-launch BIT and not a continuous BIT post-launch – a continuous BIT would be “nice to have” and desirable but is not a hard requirement.)

The FTS must meet RCC-319 as negotiated with the RSOs. Telemetry standards are defined in IRIG Standard 109. C-Band Transponder Standards are defined in RCC 254. If launching from a submarine, S9510-AB-ATM-010 must be followed. For the current MRSS kit, this applies to the Lithium Thermal Battery.

For encryption, the MRSS or certain subsystems thereof must follow NSA requirements and procedures regarding accounting, handling and safeguarding the Controlled Cryptographic Item (CCI) and keys; i.e., the encryption chip is a CCI and key erasure is a required function.

Asset Recovery: Whereas the current Tomahawk testing requirement does not include a need to recover the missile by use of a parachute, that capability may be required in the future. Offerors are requested to

consider innovative ways to include that potential capability if possible within the design constraints of the missile. Offerors should consider design options for land and deep-water recovery.

Other Key Requirements:

- The MRSS may not adversely impact or degrade operational performance of the Tomahawk missile
- The FTRs must meet redundancy requirements as outlined in RCC-319.
- The MRSS must meet MIL-STDs for shock and vibration, environmental, etc.
- The MRSS must ensure that any re-certification requirements of subsystem/parts are not less than 3 years.
- Service life must exceed 10 years.
- Unit cost must not exceed \$1.0M

The RSO at each flight test range has ultimate authority on all Flight Terminate System matters. The current MRSS design has an embedded NSA encryption chip within the MRSS and keys utilized for operations that enable telemetry encryption. What these statements mean is there are two external Program Office organizations that could significantly affect the MRSS design.

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. 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: Design, develop, and demonstrate the feasibility of a range safety subsystem that supports flight testing of the Tomahawk Weapons System on capable Government open-air test ranges in accordance with the parameters provided in the Description. The MRSS Spec and the TT-SRD-98-0058 System Safety Program Plan will be provided to the Phase I awardees. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Based on the design developed in Phase I, produce a full-scale, operational prototype of the new MRSS. Develop test procedures for demonstrating and validating MRSS. Demonstrate and validate capability to meet range safety requirements.

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

PHASE III DUAL USE APPLICATIONS: Develop and provide a Product Level Technical Data Package according to MIL-STD-31000B for the MRSS that includes applicable drawings and any special tooling. Finalize and transition to applicable programs.

Successful technology development would benefit the commercial flight safety testing industry.

REFERENCES:

1. "Document 319-19, Flight Termination Systems Commonality Standard." Range Safety Group, Range Commanders Council, White Sands Missile Range, June 2019.

https://www.wsmr.army.mil/RCCsite/Documents/319-19_FTS_Commonality/319-19_FTS_Commonality.pdf

2. "MIL-STD-31000B, MILITARY STANDARD: TECHNICAL DATA PACKAGE (TDP) (31-OCT-2018)." http://everyspec.com/MIL-STD/MIL-STD-10000-and-Up/MIL-STD-31000B_55788/
3. "MIL-STD-1385B, MILITARY STANDARD: PRECLUSION OF ORDNANCE HAZARDS IN ELECTROMAGNETIC FIELDS, GENERAL REQUIREMENTS FOR (01 AUG 1986)." http://everyspec.com/MIL-STD/MIL-STD-1300-1399/MIL-STD-1385B_18455/
4. "MIL-STD-1472F, DEPARTMENT OF DEFENSE DESIGN CRITERIA STANDARD: HUMAN ENGINEERING (23 AUG 1999)." http://everyspec.com/MIL-STD/MIL-STD-1400-1499/MIL-STD-1472F_208/
5. "MIL-HDBK-1512, DEPARTMENT OF DEFENSE HANDBOOK: ELECTRO-EXPLOSIVE SUBSYSTEMS, ELECTRICALLY INITIATED, DESIGN REQUIREMENTS AND TEST METHOD (30 SEP 1997)." http://everyspec.com/MIL-HDBK/MIL-HDBK-1500-1799/MIL_HDBK_1512_1843/
6. "MIL-I-23659C, MILITARY SPECIFICATION: INITIATORS, ELECTRIC, GENERAL DESIGN SPECIFICATION FOR (31 AUG 1972)." http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-I/MIL-I-23659C_31545/

KEYWORDS: Mid-Body Range Safety Subsystem, MRSS, Tomahawk Weapons System, RSEU, Flight Termination, Readiness, Lethality

N202-114

TITLE: High Fidelity Electromagnetic Design, Prediction and Optimization of Airborne Radomes

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

TECHNOLOGY AREA(S): Air Platform

OBJECTIVE: Define and develop a methodology by which high fidelity computation of antenna performance parameters of an installed system is utilized, and then apply that methodology to optimize the design of a radome covering an antenna.

DESCRIPTION: Currently, the computational tools used to design advanced airborne radomes are limited in their ability to predict and achieve installed performance over the full range of operating conditions [Ref 1]. The design and/or analysis of complex radomes with locally varying curvature and thickness, that incorporate metamaterials or frequency-selective surfaces (FSSs), is especially complex. Only full-wave electromagnetic analysis of the antenna cavity and radome structure can provide the required accuracy in predicting the variations in performance measures such as power transmission and reflection, boresight error, and sidelobe levels over the field of view. Such analyses can also reveal the levels of cross-polarization, grating lobes, and modifications of currents on the antenna structure resulting from electromagnetic coupling among the various structures in the antenna cavity. Providing that they can generate timely and accurate results, high fidelity predictions play a key role in extending the scope and accuracy of the design process for multilayer radome designs having complex internal structure, such as A-sandwich, C-sandwich, Prepreg, honeycomb/foam core, and Rohacell.

The Navy is interested in improving and optimizing the performance of radar systems already installed on Navy aircraft. The design of radomes currently covering such systems are to maximize transparency and beam quality at all viewing angles for in-band operation, and to minimize sidelobe levels. Structural, aerodynamic, and material-property considerations impose constraints that limit the design optimization process. Moreover, the optimization is performed using computational electromagnetics (CEM) tools with inherent approximations of the physical electromagnetic behaviors. Thus, the end-result is a less than optimal system that introduces uncertainties in the radar's modes.

Recent progress in the development of full-wave electromagnetic solvers provides an opportunity to apply the detailed predictions to optimize actual radome designs [Ref 2]. The goal of this SBIR topic is to establish one or more methodologies based on full-wave solvers that will have the following characteristics:

1. High fidelity in predicting all operational characteristics of radome-enclosed antenna arrays as installed on Navy aircraft including effects due to interaction with aircraft structures external to the antenna cavity. This entails precise descriptions of the elements and layers comprising the radome, as well as auxiliary structures such as lightning strips and pitot tubes inside the cavity.
2. Modelling of electrically large radomes that will require advancements in high-order, full-wave solvers in the following areas:
 - a. high order curved meshing;
 - b. cell sizes larger than a wavelength to fill the volume domain with fewer cells
 - c. high-order absorbing boundary conditions (ABC) that can bring the outer boundary very close to the target extruded prism and mixed cells to model very thin radome structures.
3. Effective software support of volumetric grid generation from detailed computer-aided design (CAD) models of all relevant structures. These grids will typically be multi-resolution to model critical details according to the accuracy requirements of the solver.

4. Fast execution of the solver and post-processing algorithms on massively parallel computer platforms. This capability is a high priority, as the time and resources available to perform the repeated runs required for optimization are limited.
5. Development of a highly intuitive and intelligent Graphical User Interface (GUI) to assist the user in all phases of the CEM model development, import, export, preprocessing and post-processing.
6. Flexibility in supporting a wide variety of optimization strategies, including genetic algorithms, particle swarms, and surrogates based upon the original design tools [Ref 3].

PHASE I: Design, develop and demonstrate the feasibility of a methodology to exercise a full-wave CEM code on an approved radome. Evaluate the potential of this software to adjust key details in radome design to improve actual performance metrics for the installed radar system. Demonstrate that the method is able to model various structural and material features of a complex radome. Demonstrate that the code fulfills the requirements 1-6 stated above. If not, make persuasive arguments as to how modification of the code could fulfill these requirements. The Phase I effort will include plans to be developed under Phase II.

PHASE II: Validate and mature the approach from Phase I. Develop optimization and design approaches to improve radome performance with installed antennas and interaction with neighboring structures. Develop a GUI that encompasses the entire computational process, including: preprocessing tools for geometry import and generation of high order curved elements, high order processing tools, and a comprehensive set of post processing tools for data output and visualization.

PHASE III DUAL USE APPLICATIONS: Complete the development of the CEM software application. Perform final testing and transition into use on applicable platforms. The CEM software application will have a widespread use in the DoD, industry and academia for the design, optimization, and/or analysis of highly complex radomes and electromagnetic problems. The aerospace industry as well as universities such as Massachusetts Institute of Technology (MIT), The Ohio State University (OSU) and California Poly-Technical Institute (Cal Tech) could all benefit from, or be interested in, the resulting technology.

REFERENCES:

1. Nair, R. & Jha, R. "Electromagnetic Design and Performance Analysis of Airborne Radomes: Trends and Perspectives [Antenna Applications Corner]." IEEE Antennas and Propagation Magazine, Volume 56, Issue 4, 2014, pp. 276-298. <https://ieeexplore.ieee.org/document/6931715>
2. Vukovic, A., Sewell, P. & Benson, T. "Holistic Appraisal of Modeling Installed Antennas for Aerospace Applications." IEEE Transactions on Antennas and Propagation, 2019, pp. 1396-1409. <https://ieeexplore.ieee.org/document/8558592>
3. Massa, A. & Salucci, M. "Dealing with Complexity in Electromagnetics Through the System-by-Design Paradigm - New Strategies and Applications to the Design of Airborne Radomes." 2018 IEEE Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Boston MA, pp. 529-530). <https://ieeexplore.ieee.org/document/8609182>

KEYWORDS: Computational Electromagnetics, Radomes, Frequency Selective Surfaces, Curved Surfaces, Software Application, Aerospace.

RT&L FOCUS AREA(S): Quantum, Directed Energy
TECHNOLOGY AREA(S): Air Platform

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 monolithic dual-band quantum cascade laser platform with almost beam diffraction limited output power >3 Watts each in the 4.6-5 and 3.6-4.2 micrometer bands.

DESCRIPTION: High-power, cost-effective, compact, and reliable mid-wave infrared (MWIR) Quantum Cascade Laser (QCL) platforms operating in the continuous wave (CW) regime are highly desirable for current and future Navy applications. Individual QCLs emitting within the 4.6-5 micrometer wavelength band with about 5 Watts CW output power and a wall-plug efficiency of about 20% at room temperature (RT) have been demonstrated [Ref. 1]. There is another, shorter MWIR spectral band between 3.6 and 4.2 micrometers [Ref. 2] that is also of interest for Naval applications. The atmospheric transmission in this band is about 45% to 50% higher than that of the 4.6-5 micron spectral band. Currently both QCLs emitting in both of the MWIR bands are beam-combined using external optical elements for current Naval applications.

While the current external beam combination configuration's size and weight may be adequate for current platform applications, other aerial platforms such as compact rotary-wing aircraft and/or smaller unmanned aerial vehicles can benefit from a laser source that is at least 20 times smaller and lighter. A monolithic laser chip platform with a single optical output aperture emitting in both wave bands using a single laser driver electronics would minimize the overall laser size, weight, and cost as stated in the specifications below. Therefore, the goal of this SBIR topic is to develop a monolithic dual-band QCL-based source that meets the following performance specifications:

1. Room-temperature CW optical power over 3W each in the 4.6-5 and 3.6-4.2 micrometer bands
2. QCL package volume less 1 cm³
3. QCL package weight less than 100 grams
4. Wallplug efficiency exceeding 15%
5. Almost diffraction limited beam quality factor with $M2 < 1.5$

Priority will be given to solutions minimizing weight and size, while meeting the optical power and efficiency requirement.

PHASE I: Develop and demonstrate the feasibility of a viable, robust, and manufacturable design for a single dual-band QCL source that meets or exceeds the requirements specified. Identify technological and reliability challenges of the design approach, and propose viable risk mitigation strategies. The Phase I effort will include prototype plans to be developed in Phase II.

PHASE II: Design, fabricate, and demonstrate a packaged dual-band laser prototype based on the design from Phase I. Test and fully characterize the laser prototype to assess its performance. Report performance results.

PHASE III DUAL USE APPLICATIONS: Fully develop and transition the high performance QCL with the specifications stated in Phase II for DoD applications in the areas of Directed Infrared Countermeasures, advanced chemicals sensors, and Laser Detection and Ranging. The DoD has a need for advanced, compact, high performance MWIR QCL In Band IVA (3.8–4.1 micron) and Band IVB (4.6–5) micrometer bands combined emissions from a single laser aperture that can be readily scaled via beam combining for current and future generation DIRCMs, LIDARs, and chemicals/explosives sensing. The commercial sector can also benefit from this crucial, game-changing technology development in the areas of detection of toxic gases, environmental monitoring, and non-invasive health monitoring and sensing.

REFERENCES:

1. Bai, Y., Bandyopadhyay, N., Tsao, S., Slivken, S. & Razeghi, M. “Room Temperature Quantum Cascade Lasers with 27% Wall Plug Efficiency.” Applied Physics Letters, 2011. <https://www.scholars.northwestern.edu/en/publications/room-temperature-quantum-cascade-lasers-with-27-wall-plug-efficie>
2. Lyakh, A., Maulini, R., Tsekoun, A., Go, R., Von der Porten, S., Pflugl, C., . . . and Patel, C. “High-Performance Continuous-Wave Room Temperature 4.0- μm Quantum Cascade Lasers with Single-Facet Optical Emission Exceeding 2 W.” Proceedings of the National Academy of Sciences of the United States of America, 2010. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2973916/>

KEYWORDS: Quantum Cascade Lasers, QCL, Band IVA, Band IVB, 3.8 Micron, 4.1 Micron, 4.6 Micron, Midwave-Infrared, Laser Array

N202-116

[Navy has removed topic N202-116 from the 20.2 SBIR BAA]

N202-117

TITLE: Optimized Subtractive Manufacturing - Right Parts, Right Time, Every Time

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

TECHNOLOGY AREA(S): Air Platform, Ground Sea, Weapons

OBJECTIVE: Develop the ability to produce optimized (strength/stiffness/weight) part geometry, using lathes and milling machines as constraints, to feed Computer Aided Manufacturing (CAM) software for machining centers.

DESCRIPTION: Currently, optimization software develops a mesh-based output for optimized parts. The user inputs the various parameters (required strength, stiffness, or weight) and the optimization code calculates the topology to meet the user requirements. This mesh-based output is not generally in a format directly usable to create a part by either additive manufacturing or subtractive manufacturing. For additive manufacturing, a second software suite is needed to process the mesh-based output into usable format to produce the part. The mesh-based output is unusable for subtractive manufacturing without significant engineering input.

Additively manufactured components have an advantage of being able to be created in complex shapes, which are unable to be made using subtractive methods. However, the use of multi-axis numerical control subtractive manufacturing machines allows similarly complex shapes to be created. The issue for subtractive based manufacturing centers around tool-path and access (e.g., can the tool get into a space and move in the same space).

The disadvantage of additive manufacturing is that both the process and material must be qualified and tested together in order to provide sufficient properties to be evaluated for airworthiness. Unlike additive manufacturing, components manufactured by subtractive manufacturing can be evaluated for airworthiness quickly by analysis. Analysis of subtractive manufactured components requires material properties from the manufacturer and part geometry in order to be evaluated for airworthiness.

This SBIR topic seeks to combine the strengths of material qualification associated with subtractive manufacturing and the benefits of optimization software to provide the best possible parts in the least amount of time. To accomplish these goals, the Navy seeks the development of a software package that performs optimization for strength, stiffness, and weight as goals while using machinability as a constraint. The output from the Computer Aided Design (CAD) in the form of a common platform independent file type (e.g., Parasolid, Standard for the Exchange of Product model data (STEP), Initial Graphics Exchange Specification (IGES), or ACIS). The output geometry should be optimized for the chosen objective and be machinable by multi-axis mill and/or lathe.

PHASE I: Design and develop a software to analyze/optimize a component for a particular objective (e.g. strength or stiffness or weight). Demonstrate the feasibility of the software to constrain the analysis/optimization using a multi-axis subtractive machine as a constraint (i.e. the component must be manufactured on a multi-axis mill or lathe). The Phase I will include prototype plans to be developed in Phase II.

PHASE II: Develop and prototype the software design from Phase I and demonstrate its ability to analyze/optimize a component for multiple objectives (e.g., strength and stiffness). The software should constrain the analysis/optimization using a multi-axis subtractive machine as a constraint (i.e., the component must be manufactured on a multi-axis mill and/or lathe). Additionally, the software should incorporate "machinability" or ease/speed of manufacturing as a constraint. Lastly, use a design as agreed upon between the United States Navy and the performer to demonstrate the software, ending with the fabrication of a component optimized for strength, stiffness and/or weight to be made on a multi-axis mill

and/or lathe. The output of the software will be a CAD file(s) of neutral file type (i.e., Parasolid, STEP, IGES, or ACIS) . The output geometry should be optimized for the chosen objectives (strength, stiffness, and/or weight) and be machinable by a multi-axis mill and/or lathe.

PHASE III DUAL USE APPLICATIONS: Validate previously developed parts optimized for multiple objectives through mechanical testing. Develop an interface to accept imported geometry from other CAD software packages. Develop a stand-alone interface or interface with an existing software company's package (e.g., Solidworks, ANSYS, ABAQUS, and/or Altair).

Successful development of this technology would benefit manufacturers and would speed the development of machined products, greatly reducing design cycles, and optimizing the performance of machined components for all industries. Both the aerospace industry and personal electronics manufacturing sector would benefit from this technology development.

REFERENCES:

1. Liu, J. & To, A. C. "Topology optimization for hybrid additive-subtractive manufacturing." Structural and Multidisciplinary Optimization, Volume 55, Issue 4, 2016, pp. 1281-1299. <https://par.nsf.gov/servlets/purl/10026127>
2. Zuo, K.T., Chen, L.P., Zhang, Y.Q., & Yang, J. "Manufacturing- and machining-based topology optimization." The International Journal of Advanced Manufacturing Technology, Volume 27, Issue 5-6, 2005, pp. 531-536. <https://link.springer.com/article/10.1007/s00170-004-2210-8>

KEYWORDS: Optimization, Machining, Modeling, Simulation, Design, Manufacturing

N202-118

TITLE: Passive System for Detection and Identification of UAVs Using Multispectral/Hyperspectral Imaging Technologies

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platform

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 a passive multispectral/hyperspectral imaging system that can identify unmanned aerial vehicles (UAVs) with high probability of detection and low probability of false alarms by exploiting the unique combined signatures in both spatial and spectral domains.

DESCRIPTION: The proliferation of the use of unmanned aerial vehicles (UAVs) of various sizes and shapes for defense, commerce, monitoring, and other applications has increased at a very expeditious pace. Along with their advantages in ease of operation and low cost, the widespread availability of UAVs has posed significant security threats in both defense and civilian arenas.

Various approaches have been explored to interdict UAVs [Refs 1-3]. However, these interdiction strategies typically presume that the drone has already been detected. As part of the effective UAV threat mitigation, it is first necessary to have the ability to detect and track UAVs in the airspace. Straightforward adoption of currently fielded airspace surveillance technologies will not suffice as UAVs are much smaller in physical size and fly slowly at lower altitudes. For instance, a conventional air surveillance radar system (operating at L-band or S-band) rely on the radar cross section (RCS) of an aircraft for detection, but this may not always provide reliable detection in case of UAVs. Even if a dedicated system is sensitive enough to detect an object like a small UAV, just RCS information alone is not adequate. Some birds are similar in physical size to small UAVs and fly at similar altitudes and speeds. Visual detection of UAVs does not effectively discriminate between a small UAV, a bird or a plastic bag caught in the wind.

Recent technological advances have made long-wave infrared (LWIR) and mid-wave infrared (MWIR) hyperspectral imaging (HSI) in the 3-5 and 8-12 micrometer wavelength ranges a viable technology in many demanding military application areas where materials can be identified by their spectral signatures. Further, LWIR spectral range offers advantages that are unmatched by the visible and short-wave infrared range as LWIR is not susceptible to performance degradation from scattering by water-based aerosols, dense fog and clouds in the atmosphere. Hence, the operational utility of LWIR and MWIR HSI for detection, recognition and identification of hard-to-detect targets in environments cluttered with background noise is especially critical. HSI sensors provide image data containing both spatial and spectral information. The spectral information offers the additional modality to address such detection tasks that are unachievable by spatial information alone. The spectral information of an HSI stems from the fact that the amount of radiation reflected, absorbed, or emitted - i.e., the radiance - varies with wavelength. HSI sensors measure the radiance of the materials within each image pixel area over a very large number of contiguous spectral wavelength bands.

It is the objective of this program to explore and develop MWIR and LWIR HSI technologies for the detection, acquisition and tracking of a UAV or UAVs during counter UAV surveillance that cannot otherwise be detected using more conventional imaging or radar. The goal is to perform an exploration and investigation of both MWIR and LWIR hyperspectral signatures of UAVs against various environmental backgrounds, such as sky backgrounds both in day time and night time, to design an effective detection and tracking algorithm with high probability of detection and low probability of false alarm at a range up to 10 km. The detection and identification algorithm should be combined with system designs that employ either innovative sensors or commercial off-the-shelf (COTS) systems. The result should be an effective UAV detection and identification algorithm based on MWIR and LWIR HSI systems with probability of detection more than 90% and probability of false alarm less than 10% at the detection range up to 10 km even at the presence of common atmospheric obscurants, such as fog, clouds and aerosols, where atmospheric obscurants can reduce the visible transmission coefficient at detection distance down to less than 10% relative to that in vacuum. The identification algorithm of the system should incorporate a library of UAVs that will keep pace with those that are available.

PHASE I: Design, document and demonstrate feasibility of a detection and tracking algorithm based on the combined LWIR and MWIR HSI systems of the developer's choice that meet or exceed the requirements specified in the Description. Identify the technical risk elements in the detection and tracking algorithm design and provide viable risk mitigation strategies. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Construct, develop, and demonstrate a combined HSI system with the associated detection/tracking algorithm based on the design from Phase I. Conduct quantitative measurements and analysis of the system prototype and assess system performance against the stated requirements. Prepare a report that summarizes the experimental evaluation and validation of the performance characteristics of the developed system.

PHASE III DUAL USE APPLICATIONS: 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 UAV detection and identification, and other anomaly surveillance and reconnaissance applications.

Commercialize the detection and identification technology for commercial aviation enhanced vision, chemicals/explosives sensing, detection of toxic gases, environmental monitoring, and non-invasive health monitoring and sensing.

REFERENCES:

1. Pringle, C. "US Marines to Test Drone-Killing Laser Weapons." Defense News, Sightline Media Group, June 19, 2019. <https://www.defensenews.com/industry/techwatch/2019/06/19/us-marines-to-test-drone-killing-laser-weapon/>
2. Williams, R. "Tokyo Police are Using Drones with Nets to Catch Other Drones." The Telegraph, 11 December 2015. <https://www.telegraph.co.uk/technology/2016/01/21/tokyo-police-are-using-drones-with-nets-to-catch-other-drones/>
3. Liptak, A. "A US Ally Shot Down a \$200 Drone with a \$3 Million Patriot Missile." The Verge, March 16, 2017. <https://www.theverge.com/2017/3/16/14944256/patriot-missile-shot-down-consumer-drone-us-military>

KEYWORDS: Unmanned Aerial Vehicles, UAV, Image, Detection, Identification, Hyperspectral, Multi-Spectral

N202-119

TITLE: Cross Deck Pendant Health Monitoring

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

TECHNOLOGY AREA(S): Materials

OBJECTIVE: Develop a Cross Deck Pendant (CDP) inspection device that provides a "GO / NO-GO" result based on automatic determination of cable health.

DESCRIPTION: Carrier aviation is dependent on the ability to recover aircraft expeditiously and safely aboard ship. The arresting gear system aboard aircraft carriers relies on a steel cable to transfer the energy from the landing aircraft to the arresting gear engines located below the deck. The arresting gear cable consists of two separate cables, the CDP and the purchase cable, connected via a terminal and pin. The CDP is the portion of the cable stretched across the landing area and interfaces with the aircraft tailhook.

Automated inspections of the CDP have proven to be problematic to implement due to the challenging operating environment of aircraft carrier flight decks (i.e., steel deck with a stationary steel wire rope). Current inspection procedures take approximately two minutes, requiring sailors to visually inspect, and slide a gloved hand looking for broken wires on the arresting cable, which is currently a 1-7/16" diameter 6x30 (6 strands made up of 30 wires each) right hand lang lay steel wire rope with a polyester core. This method is subjective and relies on the expertise of the maintainer to ascertain the health of the cable. The current replacement criteria is four broken wires in one cable lay.

A simple, compact but sophisticated "GO / NO-GO" inspection indicator device available for use by Navy maintenance technicians to help increase the accuracy/reliability of the CDP inspections and cable health is sought. Currently the health of the CDP is classified by the number of broken wires present, with four broken wires requiring the CDP to be removed from operation. Solutions need to meet the performance requirements for environmental ruggedness (MIL-STD-810) and should give a simple binary decision indication on cable health [Ref 2]. The inspection device will need to operate in the following environment: on a steel deck, in all weather conditions, day and night, flight deck electromagnetic interference (EMI) conditions, and greased/kinked cables. Any proposed method that requires cable removal or destroying the cable will not be considered.

The ability to predict the cable failure location is desired, as would an estimate of remaining service life. The Navy will consider both in-situ sensors (i.e., part of the cable) and inspection tools (with handheld preferred) that are not part of the cable. However, the inspection must be accomplished while the cable is in operation.

PHASE I: Develop and demonstrate feasibility of a design solution for a handheld steel cable life indicator that can detect a single broken wire without the need for human interpretation in a timeframe that doesn't significantly exceed the current inspection time and provides a "GO / NO-GO" decision on the health of a CDP. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Build and demonstrate a prototype inspection device, and any interfacing electronics, to inspect the CDP. Final demonstration will be in a test environment representative of the CDP aboard ship.

PHASE III DUAL USE APPLICATIONS: Finalize a prototype for robustness and shock testing [Ref 2]. Test the prototype at Naval Air Warfare Center Aircraft Division, Lakehurst, New Jersey. Transition to appropriate end users.

Wire rope has a wide range of applications in industry, including bridges, elevators, cranes, overhead hoists, ski-lifts, ship moorings and off-shore oil rigs. Broken wire count is a standard method for

determining when to replace cables in everything from cranes to winches, so a method of easily identifying broken wires could be beneficial in many non-naval applications.

REFERENCES:

1. "Wire Rope User's Manual (4th ed., December 2005)." Wire Rope Technical Board.
http://www.wireropetechnicalboard.org/main_prod.html
2. "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/
3. "U.S. Navy Wire-Rope Handbook, Volume 1 - Design and Engineering of Wire-Rope Systems (Document Number: a955305)." <https://apps.dtic.mil/dtic/tr/fulltext/u2/a955305.pdf>

KEYWORDS: Wire Rope, Cross Deck Pendant, Arresting Gear, Health Monitoring, Nondestructive Inspection, NDI, Steel Rope, Cable Failure

N202-120

TITLE: Improved and More Robust Automatic Target Classifiers

RT&L FOCUS AREA(S): Artificial Intelligence/ Machine Learning, General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platform, Information Systems, Battlespace

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 better and more robust automatic target classifiers capable of providing improved accuracy, identification, and classification of complex or subtle dynamics by leveraging advanced mathematical and machine learning tools.

DESCRIPTION: Current tactical platforms are challenged when it comes to target identification and classification algorithm development. They are unlikely to routinely encounter more complex dynamics of targets of interest and when they do, the raw data is not likely to be recorded. Therefore, data from other collection systems and/or computer models must be used to model and simulate the dynamics and build the required algorithms. The advancement of powerful super computers has made near-real physical modeling possible [Ref. 1], allowing modeling of almost any target with its environment and achieving very good agreement between models and observations. It is important to note though, some approximations are usually required but those terms are generally small and are usually considered insignificant.

Advanced mathematical and machine learning techniques may be used to resolve this apparent paradox between exploiting a high-dimensional feature space with data intensive machine learning and a lack of understanding of the underlying dynamics. In addition, these techniques can enable classification somewhere near real-time, a timescale that is relevant to tactical platforms, that is on the order of seconds. With this approach, one could build and train equivalently effective algorithms with built-in physics, i.e., coupled non-linear differential expressions, to ensure the algorithms are robust. Finally, the learned physics-based models could be used to extend accurate classification to other objects of similar class using sparsely sampled data, computer models, and scaled model data.

Machine learning techniques, e.g., Support Vector Machines (SVM), Dynamic Mode Decomposition (DMD) [Ref. 5], Long Short-Term Memory (LSTM) Recurrent Neural Networks (RNN) or Convolutional Neural Networks (CNN), are effective at picking up and exploiting small differences in data, especially for spatiotemporal coupled systems where the feature space is very large in higher order dimensions. As a result, improved performance can be achieved with access to higher dimensional data with finer temporal resolution and higher fidelity. Getting this data can be difficult for a tactical platform and using traditional computer modeling may not be sufficient due to its data approximations. However, scaled model data might be used to better capture the underlying dynamics and provide a critical element for the advancement of machine learning algorithms. Scale modeling cannot be a complete alternative and may be dismissed in the development and test of classification systems because of the expense when scaling to large class.

One other important consideration when using machine learning algorithms are generalization errors or systematic biases. Because these algorithms are sensitive to high dimensional features, they can often key on intangible artifacts like non-real sensor phenomenon or peculiarities present in the data collection. The traditional black box approach sometimes makes it difficult to detect or completely eliminate these types of errors; but all attempts must be made to do so. One way to do this is to ensure the algorithms are grounded in a priori knowledge of physical laws. As with human intelligence, machine intelligence must also be confined to the realm of reality.

Recent mathematical tools have been developed that might be leveraged to resolve the apparent paradox of capturing the desired level of complexity in a machine learning algorithm and knowledge of the underlying physical mechanism it is exploiting. Examples of methods or techniques that may provide the desired results include the work by Raissi et al. [Refs. 2, 3], which has demonstrated the ability to translate noisy observations in space and time into non-linear partial differential equations. This was done by embedding a deep hidden physics layer in a Neural Network; it is able to learn the underlying dynamics during training [Ref. 2]. The resulting Neural Networks form the basis for new classes of algorithms with a priori built in knowledge of the underlying physical laws [Ref. 3]. This could allow better and more robust extrapolation to other objects within the same spatiotemporal framework using limited observations and/or augmented with computer and scaled model data. Another example of a technique used for complex dynamics is Dynamic Mode Decomposition [Ref. 5], which have shown the capability to extract governing equations of a dynamic system from sensor and image data collected on that system.

Combining new mathematical tools, hidden physics layers, scaled and computer models, and sparse observational data, it should be possible to build better and more robust intelligent machine learning algorithms. These new systems could process higher-dimensional input data at the same speeds or faster to achieve reduced missed identification or classification and increased correct identification and classification performance all the while providing higher confidence in those decisions. Existing data fusion metrics from Single Integrated Air Picture (SIAP) [Ref. 6] or the popular Stone Soup metrics package can be used to assess accuracy in identification and classification against existing systems as a baseline.

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. 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: Design and develop a plan for implementing physics-based machine learning using sparsely sampled and noisy scaled laboratory data. Demonstrate feasibility of a sufficiently robust system to handle, and complex enough to leverage, spatial and temporal coupling and dynamic motion. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Based upon the plan from Phase I, develop a machine-learning classification algorithm for multiple targets with separate quarantined targets. The targets can be any class with spatial and temporal dynamics. Build a well-trained SVM, LSTM RNN, CNN classifier using physics-based hidden layers and scale model representations. Test and demonstrate the extent to which sparsely and/or noisy data from the

quarantined target can be incorporated into the existing classifier. Test and demonstrate the extent to which the trained hidden physics layer can produce representative data that matches existing computer or scaled model data. Demonstrate the ability to generate data or a model that is robust against a well trained SVM or CNN classifier. The performance of the developed algorithm may be tested on an approved data set for validation.

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

PHASE III DUAL USE APPLICATIONS: Extend the work to include real world data and accurate representative models. Transition the algorithm to appropriate military and commercial users. Heavy commercial investments in machine learning and artificial intelligence will likely continue for the near future. Better and more robust machine learning signal processing and classification has a myriad of commercial uses including financial market prediction, self-driving cars, medicine, and environmental research.

REFERENCES:

1. Abdulle, A., Weinan, E., Engquist, B. & Vanden-Eijnden, E. "The heterogeneous multiscale method." *Acta Numerica*, 21, 2012, pp. 1-87. doi:10.1017/S0962492912000025
2. Raissi, Maziar. "Forward-Backward Stochastic Neural Networks: Deep Learning of High-dimensional Partial Differential Equations." Division of Applied Mathematics, Brown University, 2018.
<https://arxiv.org/pdf/1804.07010.pdf>
3. Raissi, M. "Deep hidden physics models: Deep learning of nonlinear partial differential equations." Division of Applied Mathematics, Brown University, 2018. ArXiv:1801.06637 [Cs, Math, Stat].
<https://arxiv.org/pdf/1801.06637.pdf>
4. "2018 National Defense Strategy." United States Congress.
<https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>
5. Manohar, K., Kaiser, E., Brunton, S. L. and Kutz, J. N. "Optimized Sampling for Multiscale Dynamics." *Multiscale Modeling & Simulation*, 17:1, 2019, pp. 117-136.
<https://epubs.siam.org/doi/abs/10.1137/15M1023543?mobileUi=0&>
6. Votruba, P., Nisley, R., Rothrock, R. and Zombro, B. "Single Integrated Air Picture (SIAP) Metrics Implementation." Single Integrated Air Picture Systems Engineering Task Force, 2001.
<https://apps.dtic.mil/dtic/tr/fulltext/u2/a397225.pdf>

KEYWORDS: Scale Model, Machine Learning, Hidden Physics Layers, Non-Linear Differential Equation, Advanced Mathematics, Automatic Target Qualifier

N202-121 TITLE: Identifying and Characterizing Cognitive Sensor Systems in Tactical Environments

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

TECHNOLOGY AREA(S): Air Platform, 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 methods to remotely probe an adversary's cognitive sensor system in order to characterize the nature of their response to changing stimulus.

DESCRIPTION: Our adversaries' fielding of cognitive sensor systems rapidly adapt in response to a challenging tactical environment. These cognitive systems employ a sense-learn-adapt loop. In many instantiations, these sensing systems train continuously while operational in an unsupervised fashion to gain maximum additivity to a dynamic threat environment. For example, concepts for true cognitive electronic warfare systems envision a neural network driven sensor that "should be able to enter into an environment not knowing anything about adversarial systems, understand them and even devise countermeasures rapidly" [Ref 1]. Obviously as our adversaries field these systems, we seek methods to detect their presence and characterize their response to a changing tactical environment. The Navy seeks to stimulate these responses through its own purposeful probing in order to observe their evolving sense-learn-adapt loop responses. This understanding is vital to assessing the threat these systems pose as their adaptability poses a significant military threat.

The solution must be applicable for both Navy airborne electronic warfare and radar 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 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. 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: Design and develop conceptual methods to remotely probe an adversary's cognitive sensor system for the purpose of characterizing the nature of their response to changing stimulus. The methods should be applicable to both electronic warfare and radar systems. Perform an unclassified proof of concept demonstration to show the scientific and technical merit of candidate approaches. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Perform detailed development and demonstrate the prototype techniques in terms of operational feasibility. Prepare a detailed concept of operations describing the implementation of the

approach in the field and potential challenges in its implementation for both electronic warfare and radar systems.

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

PHASE III DUAL USE APPLICATIONS: Complete development, perform final testing, and integrate and transition the final solution to Navy airborne platforms. The general techniques might be applicable to gaining insight into web-based applications, which are cognitive in nature.

REFERENCES:

1. Pomerleau, M. "What is the Difference Between Adaptive and Cognitive Electronic Warfare?" C2/Comms, December 16, 2016. <https://www.c4isrnet.com/c2-comms/2016/12/16/what-is-the-difference-between-adaptive-and-cognitive-electronic-warfare/>
2. Dong, Y., Zhang, Y., Ma, H. et al. "An Adaptive System for Detecting Malicious Queries in Web Attacks." Sci. China Inf. Sci. 61, 032114, 2018. <https://doi.org/10.1007/s11432-017-9288-4>

KEYWORDS: Cognitive, Sensors, Adaptivity, Countermeasures, Remote Sensing, Radar, Cognitive Sensor System

N202-122

TITLE: Innovative Multi-Physics-based Tool to Minimize Residual Stress / Distortion in Large Aerospace Aluminum Forging Parts

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

TECHNOLOGY AREA(S): Air Platform, Materials

OBJECTIVE: Develop a tool to optimize the quenching process by understanding and addressing the multi-physics challenges in the inter-relationship among the stress/strain, heat, and phase transformation in order to control residual stress and reduce distortion in large aerospace aluminum forging parts.

DESCRIPTION: Naval Aviation aircraft procurement faces cost and schedule challenges where one of the major contributors is the high scrap rate of large airframe aluminum forging parts. For example, a 22% scrap rate was observed on a NAVAIR low rate initial production (LRIP) Helicopter program in 2017.

The parts were rejected for geometrical non-conformance, due to distortion induced during production stages, but mostly right after the quenching step, or post-quenching. Typical production stages start with rough machining of the forging, followed by quenching, aging, removing braces, chemical milling, semi-finish machining, finish machining, and final inspection.

To reduce the post-quenching distortion, there are two approaches: 1) Do trial-and-error runs, then pick the best one. This approach is cost prohibitive since there are endless combinations of quenching set ups, or 2) Use a prediction tool to run simulations with optimized quenching parameters yielding least distortion.

Currently available tools for reducing post-quenching distortion in large aircraft aluminum forging parts are often a set of Finite Element Analysis (FEA) software with input consist of a) geometry of parts and quench tank, and b) thermal characteristics of parts and quenching medium. Thermal parameters are entered to represent the heat transfer characteristics, but that is not sufficiently accurate, since the mechanical and metallurgical aspects of the parts are changing as well in the process, and need to be concurrently considered. Acceptable accuracy would be when all three input types (i.e., thermal, mechanical, and metallurgical) are entered into the FEA before the simulation process.

To effectively reduce post-quenching distortion in large aircraft aluminum forging parts, an innovative multi-physics-based and machine learning tool must be designed to optimize the quenching process, where the model inputs will cover all three fields: thermal, mechanical, and metallurgical, with a comprehensive understanding and control of residual stresses.

PHASE I: Develop the concept for one or more physics-based options where heat transfer, stress/strain evolution, and phase transformation can be modelled. Demonstrate feasibility of the model design. Perform a proof-of-concept demonstration that assesses the design's Technology Readiness Level (TRL)/Manufacturing Readiness Level (MRL). The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop the physics-based conceptual prototype model, and verify/validate the prototype with coupon/component/full-scale testing. Demonstrate the transition feasibility. Update TRL/MRL assessment.

PHASE III DUAL USE APPLICATIONS: Commercialize and transition the developed tool as an analytical software package. Detail a verification and validation plan, along with a demonstration of application capacity for the selected airframe components of any interested aircraft platform.

Methods and techniques developed can be included for broad use in the aerospace industry in a commercial software package for optimized quenching and to minimize residual stress/distortion in large aerospace aluminum forging parts.

REFERENCES:

1. Robinson, J., Tanner, D., & Van Petegem, S. "Influence of Quenching and Aging on Residual Stress in Al-Zn-Mg-Cu Alloy 7449." *Materials Science and Technology*, Volume 28, Issue 4, April 2012, pp. 420-430.

https://www.researchgate.net/publication/233717127_Influence_of_quenching_and_aging_on_residual_stress_in_Al-Zn-Mg-Cu_alloy_7449

2. Watton, J. "Computational Modeling and Optimization of Residual Stress for Large Structural Forgings." *Aeromat 21 Conference and Exposition*, American Society for Metals, June 2012.

https://www.researchgate.net/publication/267900582_Computational_Modeling_and_Optimization_of_Residual_Stress_for_Large_Structural_Forgings

3. Yang, X., Zhu, J.-C., Lai, Z.-H., & Liu, Y. "Finite Element Analysis of Quenching Temperature Field, Residual Stress and Distortion in A357 Aluminum Alloy Large Complicated Thin-wall Workpieces." *Transactions of Nonferrous Metals Society of China*, Volume 23, Issue 6, pp. 1751-1760.

https://www.researchgate.net/publication/275129961_Finite_element_analysis_of_quenching_temperature_field_residual_stress_and_distortion_in_A357_aluminum_alloy_large_complicated_thin-wall_workpieces

KEYWORDS: Optimized Quenching, Large Aerospace Aluminum Forging Parts, Computational Modelling, Residual Stress, Phase Transformation, Micro Structures

N202-123

TITLE: Generation of Hydrogen from Seawater, Powered by Solar PV, Leading to Cogeneration of Electricity and Potable Water

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

TECHNOLOGY AREA(S): Chem Bio Defense, Materials

OBJECTIVE: Develop a shore-based system with durable components that can be used to generate hydrogen from seawater using variable solar photovoltaic (PV) power with the purpose of producing usable electricity and potable water. (Note: The system design should take into consideration lifecycle cost effectiveness and minimizing potential contaminants from the component material into the generation of water.)

DESCRIPTION: In order for renewable energy to provide greater resilience benefits to the Navy, Marine Corps, and throughout the U.S., its variable power output must be coupled with energy storage. Development in this area focuses on electric power and ignores potable water requirements, which are arguably a bigger limiter for continuation of mission operations when the utility supply is unavailable. Energy storage involving hydrogen often produces water as a byproduct of its power generation process. Hydrogen generated from seawater has yet to be commercially viable due to the high cost of materials, short product life of components, and low efficiency of the seawater-to-hydrogen evolution process. Studies and developments over the past 5-10 years have shown different yet effective ways of generating hydrogen that is compatible with seawater and address some of the major corrosion challenges [Refs 1, 2, 3]. Combining the two hydrogen-related processes into one system and utilizing variable renewable power can provide a greater resilience benefit for both island and coastal military installations, even for those that already have on-site power and water generation capabilities. Overcoming past and current issues with hydrogen generation, including corrosion, chlorine, and expensive materials, will improve lifecycle cost effectiveness. Designing the system to be used to generate potable water will affect its design as to reduce or eliminate potential water contamination.

PHASE I: Develop and demonstrate the subsystems capable of using real or simulated variable PV power and determine at least one source of real seawater from which to generate hydrogen and convert hydrogen into electricity and water. Evaluate attributes of the system, including energy density, power density, transient dynamics, system size and efficiency, water production rate and quality, component product life, and anticipated maintenance requirements using detailed models and subscale components. The U.S. Environmental Protection Agency (EPA) safe drinking water requirements for States and Public Water Systems shall be a starting point for establishing thresholds for defining potable water and target potable water production to at least 6 L/kW [Ref 4]. Finalize the systems integration and design for a 10kW-level test-bed prototype to be used for Phase II. Provide a Phase II development approach and schedule that contains discrete milestones for testing and further development.

PHASE II: Fabricate a test-bed 10 kW-level prototype. Validate prototype capabilities using laboratory testing and at least two sources of seawater with known major differences that can potentially affect the function and output of the system. Further evaluate attributes of the system from Phase I. Design a fully functional 10kW system that can be fabricated and tested in a non-laboratory environment. As funding permits, work toward fabrication of a fully functional system.

PHASE III DUAL USE APPLICATIONS: Fabricate and test a fully functional system in a real-world environment. Acquire certifications necessary to comply with connecting to a shore-based, utility grid system. Develop documentation, such as a DD-1391 and eROI (Energy Return on Investment), for sites with high potential for this application to enable the installation to request funding for construction. While this system will benefit island and coastal military installations, it can also find applications in municipalities and community microgrid systems especially where water and power are unreliable or

require an alternate source. In addition, it can support a hydrogen economy or be applied to hydrogen powered vehicles.

REFERENCES:

1. Garcia de Jesus, Erin. “Stanford researchers create hydrogen fuel from seawater.” Stanford News, March 18, 2019. <https://news.stanford.edu/2019/03/18/new-way-generate-hydrogen-fuel-seawater/>
2. Hristovski, Kiril, Dhanasekaran, Brindha, Tibaquirá, Juan E., Posner, Jonathan D. and Westerhoff, Paul. “Producing drinking water from hydrogen fuel cells.” Journal of Water Supply: Research and Technology – AQUA, Volume 58, Issue 5, July 2009, pp.327.335. <https://asu.pure.elsevier.com/en/publications/producing-drinking-water-from-hydrogen-fuel-cells>
3. U.S. Army CCDC Army Research Laboratory. “Army hydrogen-generation discovery may spur new industry.” U.S. Army website, July 2009. <https://www.arl.army.mil/www/default.cfm?article=34794>. U.S. Environmental Protection Agency. “Drinking Water Requirements for States and Public Water Systems.” September 2017. <https://www.epa.gov/dwreginfo/drinking-water-regulations>

KEYWORDS: Seawater, Hydrogen, Fuel Cell, Solar Photovoltaic, Potable Water

RT&L FOCUS AREA(S): Microelectronics

TECHNOLOGY AREA(S): Information Systems, Sensors, Electronics

OBJECTIVE: Invent and experimentally validate one or more schemes for packaging of Multi-Chip Modules (MCM) that simultaneously satisfies the system needs for volume conservation and for the thermal and magnetic field conditions that allow proper operation of complex superconducting MCM. The approach developed must be inherently notionally scalable to 1,000's of such MCM modules/"cards" in Phase III, although the work proposed here should start with a proof that a single MCM can be operated as well as a single chip. The packaging design may assume either or both electrically and photonically realized Input/Output cabling between MCM cards and across temperature gradient, but IO work is not included in this topic.

DESCRIPTION: Direct from RF superconducting Radio Frequency (RF) receivers already offer high sensitivity, extreme bandwidth, and outstanding time domain resolution all present in 1 digital data stream. Hence, they are candidates for such ultra-wideband applications as full spectrum situational awareness and cognitively adapting Low Probability of Detection (LPD) communications. However, numerous military applications such as full-spectrum active arrays (ideal for Electronic Support Measures (ESM) and Signal Intelligence (SIGINT)) require more digitizers than offered by today's limit of 3 Analog to Digital Converters on a single chip. Even larger scaling is required for the exascale computing applications (needed by future commercial data centers, a dual use). Such scaling of the system complexity will likely progress first to circuit board-like MCM and then to card case-like subassemblies. For systems with so many die to be successful, the proper magnetic and thermal environment must be simultaneously provided to each individual die, as well as including ways to plumb in power lines and data cables without causing stray magnetic fields or difficulties in servicing the final assembly.

Conductive cooling via thermal busses is a well-demonstrated technique in spacecraft design, but demonstrations of its successful use for multiple MCM constructed of 4K niobium circuits are missing. Proper electrical functionality requires no larger than 100mK variation in the effective electronic temperature across the multi-MCM assembly at a mean temperature of around 4.5K or colder.

Any total local magnetic field present at the functional superconducting switching elements is also potentially deleterious to its proper operation, but practically an upper limit of about 4 micro-Tesla may be sufficient to guarantee proper operation. Locally produced fields associated with magnetic flux trapped in moats, screening currents, circuit bias currents, and power distribution add to the more homogeneous ambient sources such as the earth's magnetic field. So far low frequency magnetic shielding only from the uniform fields have been seriously addressed and there has been little published about oscillating (AC, e.g., clock) field reduction.

Proposers should in their Phase I proposal clarify what operational functionality their MCMs will exhibit, define a notional program work time line through the end of the base of Phase II, and identify what if any Government assistance with active Nb JJ circuit die and passive MCM design/fabrication and MCM assembly their plans require as Government Furnished Property (GFP). Of the order of 2 active and 2 passive designs sites per Phase may be assumed as acceptable GFP. The SFQ5ee and MCM processes at MIT Lincoln Laboratory are the assumed sources of any new GFP materials. Active die from previous US Government programs may be supplied by the prime or possible subcontractors if the original sponsor approves. Such GFP assistance, if any, would be negotiated following Phase I selection and again following Phase II selection. In addition, how the success of the homogeneous temperature/magnetic field suppression will be experimentally documented should be described in the original Phase I proposal.

PHASE I: Base: Generate the final designs for an individual functional 20x20 mm (or larger) MCM based on either identical or distinct active Nb JJ chips (GFP), vendor-supplied supplementary chips/structures, and passive Si carriers. Either flip the vendor-supplied parts onto the carrier or wire bond them in place. Complete a desired risk reduction test of the packaging concept before the Initial Phase II Proposal is written at the end of the base effort. Perform Thermal/ B (magnetic) field modeling via numerical simulation that may be helpful, but is not required nor sufficient in the absence of experimental validation.

Option: Complete realization of the first functional prototype and begin to iterate the most problematic aspect of the realized packaging design.

PHASE II: Base: Complete a proof-of-concept demonstration. Prove the thermal and magnetic field limits can be met in a packaged single MCM assembly without any need to substantially complicate the wiring of input signal, output data, and power to/from the outside world.

Option: Refine the techniques developed and specialize the choice of chips included in the final demonstration to focus on the class of functionality desired by the transition funding sponsor. Conclude at TRL 4 or higher.

PHASE III DUAL USE APPLICATIONS: Transition the packaging techniques to a Government program and participate in further demonstrations using fully functional chips such as a proven computation accelerator for a multiple Teraflop CPU at a commercial data center or some specifically RF receiver functionality, such as correlation functions, digital beam forming, de-interleaving, or other Digital Signal Processing (DSP) operation.

REFERENCES:

1. Gupta, D., Filippov, T. V., et al. "Digital channelizing radio frequency receiver." IEEE Trans. Appl. Supercond., vol. 17, no. 2, pp. 430-437, June 2007. [HTTP://www.com/wp-content/uploads/2010/12/Digital-Channelizing-Radio-Frequency-Receiver.pdf](http://www.com/wp-content/uploads/2010/12/Digital-Channelizing-Radio-Frequency-Receiver.pdf)
2. Hayakawa, H., Yoshikawa, N., Yorozu, S., and Fujimaki, A. "Superconducting digital electronics." Proceedings of the IEEE, vol. 92, no. 10, pp. 1549-1563, October 2004. [HTTPS://you.redo.nii.ac.jp/?action=repository_action_common_download&item_id=3657&item_no=1&attribute_id=20&file_no=1](https://you.redo.nii.ac.jp/?action=repository_action_common_download&item_id=3657&item_no=1&attribute_id=20&file_no=1)
3. Holmes, D. S., Kadin, A. M., and Johnson, M. W. "Superconducting Computing in Large-Scale Hybrid Systems." Computer 48.12 (2015): 34-42. <https://www.computer.org/csdl/mags/co/2015/12/mco2015120034-abs.HTML>
4. Jayaweera, S. K. "Signal Processing for Cognitive Radios." John Wiley Press, 2014, ISBN: 978-1-118-82493-1.- <https://www.wiley.com/en-us/Signal+Processing+for+Cognitive+Radios-p-9781118824931>

KEYWORDS: Thermal Conductivity, Thermal Boundary Resistance, Passive Magnetic Shielding, Active Magnetic Shielding, Magnetic Flux, Superconducting Flux Trapping

RT&L FOCUS AREA(S): Network Command, Control and Communications

TECHNOLOGY AREA(S): Chem Bio Defense, Sensors, Electronics

OBJECTIVE: Develop photoconductive terahertz focal plane arrays that offer large pixel count, high dynamic range, and high speed over a broad terahertz (THz) frequency range.

DESCRIPTION: Electromagnetic waves in the THz spectral band (roughly covering the 0.1 - 3 THz frequency range) offer unique properties for chemical identification, non-destructive imaging, and remote sensing. However, existing THz devices, such as THz sources and detectors, have not yet provided all of the functionalities required to fulfill many of these applications. Although Complementary metal-oxide-semiconductor (CMOS) technologies have been offering robust solutions below 1 THz, the high-frequency portion of the THz band still lacks mature devices. For example, most of the THz imaging and spectroscopy systems utilize single-pixel detectors, which results in a severe trade-off between the measurement time and field-of-view.

To address this problem, a large pixel count, high dynamic range, high speed, and broadband THz focal plane array (THz-FPA) needs to be developed. The proposed THz-FPA can operate either as a frequency-tunable continuous-wave detector or a broadband-pulsed detector. It should be able to operate over a 1 - 3 THz frequency range, while offering above 30 dB dynamic range per pixel. It should have more than 1 kilo pixels and a frame rate of at least 1 Hz. Smart readout integrated circuits to increase the data collection efficiency and frame-rate can be investigated.

PHASE I: Demonstrate a proof-of-concept THz-FPA with at least 16 pixels. Show that each pixel of the THz-FPA meets the dynamic range and bandwidth requirements. Introduce a data readout method that can maintain the large dynamic range and broad bandwidth requirements for more than 1 kilo pixels and a frame rate of at least 1 Hz. Develop a Phase II plan that includes technology integration, test and validation with representative structures.

PHASE II: Realize the THz-FPA consisting of at least 1 kilo pixels integrated with the read-out circuits. Demonstrate the functionality of the final prototype to take THz images with more than a 30 dB dynamic range over a 1-3 THz bandwidth in less than 1 second. The prototype system will vary based on the proposed approach, but it may include hardware and software. Develop technology transition plan and business case assessment.

PHASE III DUAL USE APPLICATIONS: Broadband THz Imaging focal plane arrays enable sensors for detailed feature and frequency spectrum capture that support several DoD missions, among these are battlespace target assessment, surveillance in low-visibility conditions, and nondestructive material quality control (e.g., defects/corrosion in ship, aircraft, vehicle components), and law enforcement agencies for detection of illicit drugs and narcotics, and regulatory agencies (e.g., FDA, NIFA) for detection of toxins in drug, food, and agricultural products.

REFERENCES:

1. Tonouchi, M. "Cutting-edge terahertz technology." *Nature Photonics*, 1(2),2007, pp. 97-105.

<https://www.nature.com/articles/nphoton.2007.3>

2. Al Hadi, R., Sherry, H., Grzyb, J., Zhao, Y., Forster, W., Keller, H. M., Cathelin, A., Kaiser, A., and Pfeiffer, U. R.. "A 1 k-pixel video camera for 0.7–1.1 terahertz imaging applications in 65-nm CMOS." *IEEE Journal of Solid-State Circuits*, 47(12), 2012, pp. 2999-3012.

<https://www.semanticscholar.org/paper/A-1-k-Pixel-Video-Camera-for-0.7–1.1-Terahertz-in-Hadi-Sherry/4794675927847b4dc49105f9e9467e05e4bdc8a4>

3. Burford, N. M., & El-Shenawee, M. O. “Review of terahertz photoconductive antenna technology.” *Optical Engineering*, 56(1), 2017. <https://www.spiedigitallibrary.org/journals/Optical-Engineering/volume-56/issue-01/010901/Review-of-terahertz-photoconductive-antenna-technology/10.1117/1.OE.56.1.010901.full?SSO=1>

KEYWORDS: Broadband Terahertz, Imaging, Focal Plane Array

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

TECHNOLOGY AREA(S): Information Systems, Human Systems

OBJECTIVE: Develop a user-friendly capability to create background information and long-form exercise injects derived from seeds, drawing from a catalogue of already extant background material for content.

DESCRIPTION: Information environments in situations of conflict and warfare are hectic, chaotic, and hard to predict. Military exercises and training capabilities currently lack realistic material to help them to develop Tactics, Techniques, and Procedures (TTPs) and blunt information attacks; and compete effectively in conflict situations. Warfighters require realistic training capabilities and the capability to develop, test and validate TTPs for information maneuver; this requires realistic, rapidly generated content to facilitate scenario development, enhancement and maintenance during an exercise or training experience.

Simulation of the information environment is a difficult problem. Simulating Facebook posts, blogs, and other long-form inputs (200 to 800 words) is labor-intensive and difficult to scale. Artificial intelligence breakthroughs have created new capabilities to generate realistic content that would be suitable to support an information environment simulation.

The GPT-2 model [Ref 1] and potentially other artificial intelligence solutions [Ref 2] provide useful starting points for realistic text simulation. This new language model and potentially other unsupervised multitask learners [Ref 3] have been demonstrated to perform downstream tasks in a “zero-shot” setting without any parameter or architecture modification.

The desired capability is the capacity to generate realistic information inputs for simulated training and exercise environments. The capability should be able to generate text to fit in multiple formats (Facebook, blog, other social media) - posts of 1-2 paragraphs, and long posts of 800 words (in English). The desired capability will have the ability to develop scenario materials for a refugee crisis, disaster scenario or a similar complex event; to edit and perform quality checks; to change and shift narratives; to add new events; and to catalog and index materials.

PHASE I: Define and develop an initial capability for generating 50 to 200 word (approximate) synthetically generated texts with a user interface to allow for review, editing, tagging, and flagging of the produced material for initial assessment. Produced texts should be packaged to enable the flow of the materials into databases for input into a synthetic environment reservoir for test and evaluation. Develop a Phase II plan. Phase I Option, if exercised, will expand materials to develop a catalogue of synthetic background data, improve the user interface, and institute a tagging, flagging, and automatic or semi-automatic indexing function.

PHASE II: Develop a data editor and visualization capability to assist White Cell scenario authors to create narratives, inject new discourses and gists, and review the gists, discourse material and narratives in the reservoir. Improve the fidelity and capability of the Phase I product to generate texts from background materials, created by scenario authors, that are sufficiently realistic and on topic to meet a minimum of realistic level of volume and velocity (10K tweets an hour, 100 longer (up to 800 word) posts per hour).

PHASE III DUAL USE APPLICATIONS: Develop the capability to attach discourses to personas and adjust texts to conform to target narratives and discourses, so that scenario creators can develop realistic

stories for military exercises and training. Demonstrate the capability of flowing synthetic texts into simulation technologies and tools so that they can be used in an information conflict war game scenario, inject new material, and provide a realistic volume and velocity of data for a training exercise (50K tweets/hour, 1000 posts/hour). Investigate the feasibility of the capability to synthesize texts in other languages, to answer questions, and to perform translations.

Marketing and brand name companies also require new capabilities to train staff in information conflict to support their brands when dealing with trolling, meme conflicts, and other social cyber-attacks in the information environment. Non-profits such as the Red Cross and other Western aid agencies have problems similar to the U.S. Government in defending their message against foreign attackers, seeking to diminish their reputations among target audiences.

REFERENCES:

1. “Better Language Models and Their Implications.” OpenAI, February 14, 2019. <https://openai.com/blog/better-language-models/>
2. Vig, Jesse. “OpenAI GPT-2: Understanding Language Generation Through Visualization.” Medium, 5 March 2019. <https://towardsdatascience.com/openai-gpt-2-understanding-language-generation-through-visualization-8252f683b2f8?gi=fc3e151fc89f>
3. Radford, Alec, We, Jeffrey, Child, Rewon, Luan, David, Amodel, Darlo and Sutskever. Ily. “Language Models are Unsupervised Multitask Learners.” https://d4mucfpksyvw.cloudfront.net/better-language-models/language_models_are_unsupervised_multitask_learners.pdf

KEYWORDS: National Language Processing, Artificial Intelligence, Information Operations, Military Exercises, Training

N202-127

TITLE: Electrical Energy Sensing Device for EOD Detection, Location and Diagnosis of Electronic Safe & Armed Fuzes

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

TECHNOLOGY AREA(S): Sensors, Battlespace, Weapons

OBJECTIVE: Develop an electrical energy-sensing device for Explosive Ordnance Disposal (EOD) detection, location and diagnosis of Electronic Safe and Armed Fuzes (ESAF). The sensing device must be non-invasive and should interrogate the hazard from the furthest distance at which the solution can reliably function. It should be in a hand-held form factor that is below 15 pounds, including the power supply.

DESCRIPTION: Modern munitions are making increased use of ESAF which do not provide any external indications of their status (armed or not, energized or not, working or not, etc.). [Ref 1] These essentially unknown conditions pose increased risk to United States Explosive Ordnance Disposal (US EOD) technicians working on such items.

US EOD Forces have the need to non-invasively interrogate and diagnose the status of electronic components within fuzes from Unexploded Ordnance (UXO). Electronic fuzing can consist of electronic circuits, batteries, or charged capacitors within a metal fuze that initiate the firing train of the munition. In UXO situations, the ordnance fuze may not have functioned as designed, but still contains charged capacitors or a charged battery that can still function the munition, posing a threat to EOD technicians responsible for clearing the hazard.

US EOD Forces require the ability to determine the presence of a charged or depleted battery, firing capacitor, or active circuit within an electronic fuze. The fuze may be of an unknown type, with no previous knowledge of the internal fuze design or layout. The fuze body (ogive and housing) may be metallic or plastic. In addition, depending on design, electronic safe and armed fuzes fire in response to a variety of modalities, including but not limited to: radar, thermal, infrared (IR), acoustic or vibration effects. As such, US EOD Forces would interrogate the hazard from the furthest distance at which the solution can reliably function. The fuze cannot be touched or otherwise accessed. The following are essential characteristics:

Range: To minimize the exposure to a potential hazard, the EOD technician must be able to work without contacting the UXO. If the EOD technician must be close to the ordnance item in order to function successfully, then to the greatest extent possible, the sensor should not trigger a target's area denial, anti-tamper, or self-destruct features. Maximum standoff from the UXO for a reliable detection, location, and diagnosis is preferred.

Accuracy: Determination of the presence of stored or active electrical energy. The EOD technician must be able to make a charged or depleted determination and be confident that the information is correct. Determination of the magnitude of said energy is highly desirable. The device should provide the diagnostic capability for fuze status such as armed or not, energized or not, working or not, etc.

Size, Weight, and Power (SWaP): US EOD field units have limited capability to transport equipment; therefore, size and weight should be minimized. The device should have a form factor that is handheld, and weigh less than 15 pounds, including the power supply.

Environmental: The current need for the device is for surface munition applications with an expected operating temperature range of 0 to 125 °F.

PHASE I: Demonstrate the feasibility of the concept in meeting Navy needs for an Electrical Energy Sensing Device for EOD detection, location, and diagnosis of ESAF. Establish that the concept can be feasibly developed into a useful product for the Navy. Prepare a Phase II plan.

PHASE II: Develop a Phase II prototype for evaluation. Evaluate the prototype to determine its capability in meeting the performance goals defined in the Phase II Statement of Work (SoW) and the Navy need for Electrical Energy Sensing, in this case via a device that will enable US EOD technicians to detect, locate, and diagnose an Electronic Safe and Armed Device. Demonstrate the device capabilities on a variety of configurations including, but not limited to:

- 1) Known configurations: M762A1, M767A1, or M782 fuze for artillery rounds, the M7 spider anti-personnel munitions system, fuzes with area denial or anti-tamper features or self-destruct features [Ref 2],
- 2) Unknown configurations with a variety of battery sizes and unique circuitry (IED surrogates).

Deliver a minimum of five prototypes to the Navy for evaluation.

PHASE III DUAL USE APPLICATIONS: Apply the knowledge gained in Phase II to build an advanced Electrical Energy Sensing Device suitably packaged with a power source and portable configuration. Statistically characterize the device performance to determine confidence and reliability across a selection on known and unknown ESAF configurations. Meet the desired Objective values of 80% confidence and 85% reliability. Collaborating with EOD technical and military staff, support test and validation to certify and qualify the system for US EOD use. Explore the potential to transfer the device to other military and commercial applications. Use market research and analysis to identify the most promising technology areas. Develop manufacturing plans to facilitate a smooth transition to the US EOD, as well as other industries such as construction or manufacturing technology.

REFERENCES:

1. Sauerlaender, Friedrich, Design Methodology for Safe and Arm Devices, Naval Air Weapons Center China Lake report TP8504, pp.4-5.

2. "MIL-DTL-32264, DETAIL SPECIFICATION: FUZE, ARTILLERY, ELECTRONIC TIME, M762A1 AND FUZE, ELECTRONIC TIME, M767A1 LESS BOOSTER (30-AUG-2007) [SUPERSEDED BY MIL-DTL-32264A, A CONTROLLED DISTRIBUTION DOCUMENT]." EverySpec Standards, EverySpec.com, http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-32264_54467.

KEYWORDS: Electrical-Energy-Sensor, Fuze, US EOD, Detect, Locate, Diagnose

N202-128

TITLE: Innovative Approaches in Design and Fabrication of 3D Braided Ceramic Matrix Composites (CMC) Fasteners

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

TECHNOLOGY AREA(S): Air Platform, Materials

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 technologies to design and fabricate 3D CMC fasteners for mechanically attaching CMC Propulsion and/or Structural components to metals.

DESCRIPTION: Ceramic Matrix Composites (CMCs) are attractive for propulsion applications due to their potential for higher temperature capability, weight reduction, and durability improvements. However, CMCs present design challenges due to their anisotropic properties, generally low interlaminar shear strength, low bearing strength, limited strain tolerance, and their reaction with alloy components at CMC/alloy interfaces [Ref 1]. Currently the prevalent mode of joining CMC to metals is to use metallic fasteners. Since the CMC component has lower Coefficient of Thermal Expansion (CTE), and bearing strength, it is desirable to use CMC fasteners for the attachments.

The current baseline for a CMC fastener is the Miller fastener [Ref 2], which is a 2D, laminated CMC design with a rectangular cross-section. It is susceptible to stress concentrations at the corners and failure due to delamination. As such, it has not found wide acceptance in the industry. In this topic a 3D braided solution is sought which can be fabricated to near net-shape. This will eliminate delamination as a potential failure mode and reduce scrap during production.

Proposers to this topic have to address two areas in their response. The first is to make a textile preform without over braiding over an insert as is typically done for non-uniform cross-section. Use of inserts is not desirable even if it is removed prior to consolidation as it may result in unacceptable porosity in the fastener during Pyrolysis and Infiltration Process (PIP) to consolidate the fastener.

The second area that proposers must address is the interfacial coating of the 3D fastener preform. Typical fiber coating for SiC/SiC CMC is a two layer BN/Si₃N₄, it is usually applied through Chemical Vapor Deposition (CVD) or Atomic Layer Deposition (ALD). The coating protects the CMC fibers during high temperature CMC consolidation. Applying it to a 3D preform could pose a challenge due to the tortuous path the gases have to take through the preform and there is a risk some portions of the preform may not be coated. It is important that the proposers articulate their approach.

Successful completion of the program will result in an enabling technology to join CMC components to metals. This technology is targeted for future platforms but can provide retrofit solutions for existing platforms.

PHASE I: Develop an innovative attachment concept for a realistic propulsion component that would benefit from a CMC application, but where a joining approach to an alloy is required as a critical enabler.

Determine feasibility through analysis, fabrication, and testing of sub-element samples under thermal and mechanical environments.

To evaluate the proposed technologies, the successful Phase I companies will fabricate SiC/SiC CMC fasteners that are 2 in. long, 0.375 in. diameter with a 45 degree countersink angle at the head. To prove feasibility the performers will provide: (1) Braid architecture design and estimate of the mechanical strengths, (2) evidence of successful coating through appropriate testing using SEM and/or FTIR, (3) evidence of matrix infiltration through porosity measurements, and (4) mechanical, wear, and recession data for fastener strengths under tension and shear which will be compared against their initial predictions. Finally, since CMC fasteners are not typically threaded, the performer will demonstrate using a flat CMC panel and metal plate the attachment scheme for securing the CMC panel to metal plate.

PHASE II: Design, fabricate, and test prototype samples to a specific component to thoroughly validate the capability of the approach. Test an engine component employing the joining methodology in a representative rig or engine environment to validate the approach.

PHASE III DUAL USE APPLICATIONS: Optimize the attachment/restraint methodology. Productionize and qualify the improved component.

The commercial airline industry, military aircraft, aerospace industry, and high-performance automobile industry seek CMC joining as a critical enabler for reducing weight and increasing efficiencies.

REFERENCES:

1. Evans, Anthony G, "Implementation Challenges for High-Temperature Composites." International Science Lecture Series, Fifth Lecture. Washington, D.C.: National Academy Press. National Research Council (U.S.). Naval Studies Board, and United States. Office of Naval Research. 1997.
2. Miller, et al., "Composite Fastener for Use in High Temperature Environments", US Patent 6045310, Apr 4 2000.
3. Kyosev, Y, "Advances in Braiding Technology: Specialized Techniques and Applications", Elsevier, Cambridge, 2016

KEYWORDS: Ceramic Matrix Composite (CMC), Joining, Fastening, Attachments, 3D preforming

N202-129

TITLE: Noretip Ablation Sensor and Telemetry Interface Unit for Hypersonic Vehicle Thermal Protection Systems

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Materials, Sensors, 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 an ablation rate sensor array and telemetry interface unit for fielding on Navy experimental hypersonic flight vehicles equipped with Extended Navy Test Bed (ENTB), or similar, telemetry units.

DESCRIPTION: The Navy performs many Submarine Launched Ballistic Missile (SLBM) flight tests. Some of these Navy SLBM test vehicles fly with an ENTB telemetry unit. The ENTB takes sensor outputs from on-board devices and transmits them to a ground station. The opportunity presented by this topic is to develop an ablation rate sensor technology for carbon/carbon nosetips, to package the sensor technology suitable for the Navy nosetip application, and to provide an electronic interface unit so as to pass the ablation rate data to an on-board telemetry unit such as an ENTB.

The ablation sensor array and interface unit electronics must be compatible with all Navy SLBM flight test requirements (size, weight, mass props, environment, shock/vibe, radiation, etc.). These requirements, as well as information for integration with the ENTB and any information necessary to demonstrate proof-of-concept, will be provided by the Navy to Phase I awardees at the time of award.

A non-intrusive ablation rate sensor technology is preferred over intrusive methods and should be able to resolve length changes to less than 0.01" (target) and 0.025" (threshold). As a non-intrusive method, ultrasonics have shown the ability to detect defects in carbon/carbon composites [Ref 4] and may be suitable for detecting length changes by use of front-face reflection. In the past an ultrasonic method has been used to measure length change of Tungsten nosetips due resonant frequency changes, as well as a bremstahlung radioactive gauge technique [Ref 5]. There has also been some recent work on a focused ultrasonic technique to measure surface loss [Ref 6]. However, proposals based on other non-intrusive methods are welcome.

Intrusive methods could include embedded wires or fiber optics such as cited in [Ref 7], but proposal of an intrusive method must demonstrate applicability to a 3D carbon/carbon composite via a pre or post manufacturing technique. Pre-manufacture must demonstrate survivability through the carbon/carbon manufacturing process. Post manufacture must demonstrate no impact on component performance or survivability.

The back face of ablating components, where it is assumed sensors will be located, will experience some short-term elevated temperature conditions. Sensors must have some degree of elevated temperature survivability.

Bulk graphite and mechanical ablation are acceptable as a means of demonstrating sensor technology during Phase I. The Navy has a limited amount of non-tactical carbon/carbon material that may be provided to the successful Phase II proposer(s). Suppliers proposing intrusive, pre-manufacture methods should provide their own materials and must demonstrate survivability through the extreme elevated temperature and highly reactive carbon/carbon process environment.

PHASE I: Identify ablation sensor technology and demonstrate bread-board ability to resolve length change on representative material within 0.025 (threshold) and 0.01" (target). Develop architectures and schematics for the interface unit of a sensor array to the ENTB. Prepare a Phase II plan.

PHASE II: Based on requirements provided by the Navy, develop a prototype unit suitable for proof of concept demonstration under Navy-funded extreme ground test environment (arc jet test for ablation rate) with Navy-supplied carbon/carbon ablative test materials. Ensure that the electronic devices used on prototype unit are suitable for the Navy flight test environment.

PHASE III DUAL USE APPLICATIONS: Develop and produce flight test units for fielding on Navy experimental flight tests. This ablation sensing technology will be applicable on reusable commercial rocket components such as carbon/carbon throats and/or nozzles.

REFERENCES:

1. Navy Conventional Prompt Strike. <https://news.usni/2018/11/21/navy-developing-prompt-global-strike-weapon-launch-sub-surface-ship>
2. Navy Strategic Systems. <https://www.ssp.navy.mil>
3. ENTB. <https://www.defenseindustrydaily.com/243M-to-Draper-Laboratory-for-Trident-II-D5-Guidance-System-Support-06004/>
4. Poudel, A., Strycek, J. and Chu, T. "Air-Coupled Ultrasonic Testing of Carbon/Carbon Composite Aircraft Brake Disks." Materials Evaluation, 71, pp. 987-994, 2013. https://www.researchgate.net/publication/262639867_A_Circular_Air-Coupled_Ultrasonic_Testing_Technique_for_the_Inspection_of_Commercial_CarbonCarbon_Composite_Aircraft_Brake_Disks
5. 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
6. 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, Jan 2012.
7. Koo, J., Natali, M., Lisco, B. et al, "A Versatile In-Situ Ablation Recession and Thermal Sensor Adaptable for Different Types of Ablatives." 56th AIAA SciTech Forum, Kissiminee, FL, 2015. <https://arc.aiaa.org/doi/abs/10.2514/6.2015-1122>

KEYWORDS: Carbon/carbon, Thermal Protection System, Ultrasonic Sensors, Ablation Rate, Hypersonic, Reentry

N202-130

TITLE: Cold-water Diving Wetsuit

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

TECHNOLOGY AREA(S): Materials, Bio Medical

OBJECTIVE: Develop and demonstrate an insulated wetsuit for cold-water (35 °F) diving, capable of maintaining 75% of its surface insulation rating to 100 foot depth. Surface insulation rating equivalent to 2 air gaps is sought using new approaches, possibly sealed multiple layers and minimized flushing of ambient water in the wetsuit.

DESCRIPTION: Most Special Operations Forces (SOF) diver training and operations is still done in wetsuits. For cold-water operations, and with basically all wetsuits being neoprene, hypothermia is a serious risk. Neoprene wetsuits provide very limited time at the surface and provide roughly 1/4 the insulation at 100 feet depth. A new wetsuit construction is desired, one that has R ratings in the single digits, comparable to a double air-gap of roughly R3-5. An innovative multi-layer approach (e.g., drop-stitch, additive manufacturing, multiple coveralls, outer fur) is sought that maintains a smaller gap or has stop-gap materials, which minimize thermal bridging, such that the R-value at 100-foot depth is 75% of the value at the surface. Innovative solutions to minimize flushing inside the wetsuit with cold ambient water will be most important. Mobility, and don and doff times should be comparable or better to those of current wetsuits. Solutions should not focus on gases composition within the gap, other than air, for ease of usage, maintenance, and repair.

PHASE I: Define and develop a design for a cold-water (35 °F) wetsuit and analyze and specify the anticipated insulation value (R-value), where it arises from and how it improves on current COTS wetsuits. Prepare designs that are sufficiently detailed to specify all materials needed, their availability, how they will be implemented, and the overall wetsuit thickness. Specify how the design reduces flushing of external/ambient water through the wetsuit. The wetsuit material, its seams (both intergarment and at wrists, neck and feet), and any closing mechanisms must stand up to typical special operations underwater diver activities and approximately 100 dives. The design created in Phase I should lead to plans to build a prototype unit in Phase II.

PHASE II: Develop, fabricate, lab-test (R-value and chiller-tank performance), and provide two suits for form, fit, and function evaluation by operational Navy divers in cold-water maritime environments. Within the period of performance, revise the design and refabricate an additional 10 units based on feedback.

PHASE III DUAL USE APPLICATIONS: Assist the Navy in transitioning the technology to operational use by Naval Special Warfare, support the Navy for test, validation, and qualification of the system for use by Navy divers, and develop commercial variants suitable for recreational divers and use in the gas-oil industry or research community. Create a marketing plan for reaching recreational users and mass production, to bring the per unit cost down to under five hundred dollars.

REFERENCES:

1. Beckman, F. L. "Thermal Protection During Immersion in Cold Water." Proceedings of the Second Symposium on Underwater Physiology, No. 1181, National Academy of Sciences, -National Research Council, Washington, D. C., 1963, pp. 247-266. <https://www.amazon.com/THERMAL-PROTECTION-DURING-IMMERSION-WATER/dp/B00A1019DG>
2. Piantadosi, C. A., Ball, D. J., Nuckols, M. L. and Thalmann, E. D. "Manned Evaluation of the NCSC Diver Thermal Protection (DTP) Passive System Prototype." US Naval Experimental Diving Unit

Technical Report (NEDU-13-79), 1979. http://archive.rubicon-foundation.org/xmlui/bitstream/handle/123456789/3356/NEDU_1979_13.pdf?sequence=1

3. Bardi, Jason S. "How Does Fur Keep Animals Warm in Cold Water?" American Physical Society, College Park, MD, November 23, 2015. <https://www.aps.org/units/dfd/pressroom/news/2015/upload/7pr-animals2015.pdf>

4. Vrijdag, Xavier et al. "Argon used as dry suit insulation gas for cold-water diving." Extreme Physiology & Medicine, 2:17, 2013. <http://www.extremephysiolmed.com/content/2/1/17s>

5. Bardy, Erik et al. "A comparison of the thermal resistance of a foam neoprene wetsuit to a wetsuit fabricated from aerogel-syntactic foam hybrid insulation." J. Phys. D: Appl. Phys., Vol. 39, Number 18, 1 September 2006, <https://iopscience.iop.org/article/10.1088/0022-3727/39/18/018/meta>

KEYWORDS: Diving, Wetsuit, Cold-water, Hypothermia, Insulation, Heat Loss

RT&L FOCUS AREA(S): Microelectronics

TECHNOLOGY AREA(S): Air Platform, Ground Sea, Materials

OBJECTIVE: Develop an intelligent laser-based system for powering, sensing, and communicating between a centralized health management unit and all the different nodes, sensors, and actuators of a platform-wide distributed fiber optic network for Condition Based Maintenance Plus (CBM+) of Naval platforms.

DESCRIPTION: For predictive maintenance of Naval platforms (ships, aircraft, submarines, UXVs), the primary degradation modes (fatigue, micro-cracking, vibration, impact damage, delaminations, heat damage, etc.) of systems aboard platforms (Hull, Structural, Mechanical, Electrical, Propulsion, Drive, etc.) need to be detected, classified and monitored as early as possible within their life cycle (incubation, nucleation, coalescence, propagation, steady growth, unstable growth) to help plan appropriate maintenance action in a safe and cost-effective manner. To accomplish this in a reliable manner, these systems need to be monitored continuously during operations and/or while at rest to the finest resolution possible (from micro to macro scales). Until now such a feat would require a large number of electrical-based sensors of different types (thermocouples, strain gauges, accelerometers, acoustic emission sensors, ultrasonic transducers, etc.) - each one with its own power and shielded cables, signal conditioning boxes in close proximity, data loggers, and signal processors. A system of this type is not practical, with too many parts, too many cables, with requirements for electromagnetic (EMI) shielding, adding significant weight to the platform, and possibly requiring more maintenance (sensor recalibration, re-soldering, prone to corrosion) than avoiding it.

Fiber optic technology offers the possibility of performing all those monitoring activities simultaneously with a single optical fiber in a distributed fashion without corrosion or EMI issues and in a safe and cost-effective manner. For this purpose, different types of Bragg grating (BG)-like sensors would be engraved in a single fiber and interrogated from one end with a multi-laser-based interrogation unit. Cost-competitive approaches already exist in the market and new ones are being developed that can monitor temperature and strain at frequencies of up to 100 Hz or impact events and vibration in the 100 Hz to 10 kHz range with BG grating sensors engraved in a single optical fiber of up to a kilometer and interrogated continuously with a single or multiple laser based system. The challenge is expanding the range of applicability to reliably detect small amplitude, high frequency (10kHz - 1MHz) acoustic emission events from growing cracks, spallation, fretting from faying surfaces or other damaging mechanisms at many points in the same fiber in a cost-effective manner. A possible solution would be to engrave a large number (around 100 or as many as technically feasible) of very sensitive sensors in an optical fiber with very narrow spectral features (less than 10 picometer spectral width) such as BG Fabry-Perot, pi-BG, or other BG-like sensors. These sensors could then be interrogated with a small number (between 4 - 8 or the fewest possible consistent with reliability of detection) of low noise, high sensitivity (able to achieve a strain sensitivity of 100 femto-strain/sqrt(Hz) or better in the frequency range from 10 kHz – 1 MHz), tunable lasers (over an entire band or more) managed by an intelligent system (machine learning, neural network or neuromorphic processor) that is informed by all the sensors (low, mid and high frequency) in the network and that can position the tunable lasers dynamically on sensors near hot spots as they develop on the system being monitored. Neither the intelligent neural processor nor cost-effective (around \$1,000/laser module or less), small footprint (4 sq. inches), low noise, high sensitivity, tunable lasers exist today. Most multichannel telecommunication lasers have poor frequency noise performance in the region of interest (10kHz - 1 MHz). Also, these lasers are only available in the C-band and L-band for long distance communications (100s of kilometers) but for CBM+ applications one typically only monitors distances of less than a few 100 meters where other bands could be used.

This topic seeks innovative approaches to develop and commercialize a cost-effective, intelligent, multi-laser based system for CBM applications. The intelligent laser based fiber optic (FO) CBM system will have high strain sensitivity to detect low amplitude, high frequency and short duration ultrasonic bursts of energy generated by growing cracks or other sources. The system should operate in one of the standard communication bands and monitor close to one hundred sensors in a long optical fiber. When designing a system, the team should be aware that the background temperature around the sensors can vary by 10's of degrees Fahrenheit in a few minutes thereby requiring feedback control to compensate for thermal drifts. Since the number of hot spots will increase over the operational life of the component/vehicle, it is desirable that the system is designed so that it can easily expand to incorporate and manage more intelligent lasers. Ultimately (not in this SBIR topic), the intelligent system should be able to learn and reconfigure itself not just based on the data from all the sensors in the fiber optic network, but also from the other sources of information such as platform operations, environmental conditions, maintenance actions, structural drawings, system changes and others.

PHASE I: Define and develop a concept for a cost-effective, intelligent, multi-laser based system operating in one of the standard communication bands for monitoring close to one hundred (or as many as technical feasible) fiber optic sensors in a single long optical fiber. These sensors will have high strain sensitivity to detect low amplitude, high frequency, low duration, ultrasonic bursts of energy generated by growing defects. For validation purposes, and to help with the down selection for the Phase II effort, the team will conduct a laboratory demonstration of a bench top system. (Note: Due to the cost restrictions of a Phase I effort, the laser system will have a minimum of one benchtop, narrow band, high sensitivity (able to achieve a strain sensitivity of 100 femto-strain/sqrt(Hz)) or better in the frequency range between 100 kHz-1MHz), tunable (over an entire band), low-cost laser. The intelligent aspects of the system will also be kept to a minimum during the Phase I to maximize resources for the laser development.) Ensure that a minimum of three fiber optic sensors (more if the budget allows) are engraved in a long optical fiber (with the sensors effectively spatially and spectrally spaced to demonstrate performance). Prove that the three sensors can detect acoustic emissions (AE) events when coupled to a 3' x 3' x 1/8" square aluminum plate (more plates and sensors are desirable if the budget allows). Use pencil lead break tests (ASTM E976010 Standard) to simulate acoustic emissions from growing cracks. If the budget allows, perform multiple tests that demonstrate the intelligence of the system such as by showing how it can classify different sources of AE signals in real-time or by showing how it can preposition the laser or lasers among the sensors based on knowledge gained from previous measurements. The system that demonstrates the best performance and the capability to cost effectively expand further will be selected for Phase II.

PHASE II: Produce an integrated, ruggedized, cost-effective, intelligent, multi-laser based system prototype operating in one of the standard communication bands for monitoring close to one hundred (or as many as technically feasible) fiber optic sensors along a single long fiber to detect low amplitude, high frequency, low duration, ultrasonic burst of energy generated by growing defects. The final prototype will include a minimum of 8 tunable lasers. For validation purposes, a long optical fiber with a minimum of 24 fiber optic AE sensors will be attached to the perimeters of a minimum of three 3' x 3' x 1/8" square aluminum plates (more plates and sensors are desirable if the budget allows). If the budget allows it is desirable that other fiber optic sensors are engraved in the same optical fiber that simultaneously monitor parameter such for temperature, strain, vibration or others. The team will perform multiple experiments to demonstrate the sensitivity, adaptability and intelligent characteristics of the system.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for fleet use through test and validation to qualify and certify the system. Further refine the prototype for production and determine its effectiveness in an operationally relevant environment. A system of this nature could have a large number of commercial applications such as for structural health monitoring of civil aviation aircraft, oil tankers, bridges, and oil and gas pipelines for both integrity and security-related needs.

REFERENCES:

1. Zhang, Qi, et al. "Acoustic emission sensor system using a chirped fiber-Bragg-grating Fabry–Perot interferometer and smart feedback control." *Optics letters*, Vol. 42, Issue 3, 2017, pp. 631-634. <https://www.osapublishing.org/ol/abstract.cfm?uri=ol-42-3-631>
2. Rosenthal, Amir, Daniel Razansky, and Ntziachristos, Vasilis. "High-sensitivity compact ultrasonic detector based on a pi-phase-shifted fiber Bragg grating." *Optics letters*, Vol. 36, Issue10, 2011, pp. 1833-1835. <https://www.osapublishing.org/ol/abstract.cfm?uri=ol-36-10-1833>
3. Hu, Lingling and Han, Ming. "Reduction of laser frequency noise and intensity noise in phase-shifted fiber Bragg grating acoustic-emission sensor system." *IEEE Sensors Journal*, Vol. 17, Issue15, 2017, pp. 4820-4825. <https://ieeexplore.ieee.org/document/7950902>

KEYWORDS: Condition Based Management Plus, Continuous Based Monitoring, Artificial Intelligence, Neuromorphic Processing, Structural Health Monitoring, Optical Fibers, Bragg Gratings, Acoustic Emission, Ultrasound Generation, Sensors and Actuators, Crack Detection

N202-132

TITLE: Novel Methods to Mitigate Heat Exchanger Fouling

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

TECHNOLOGY AREA(S): Ground Sea

OBJECTIVE: Develop fouling mitigation techniques to prolong performance of seawater heat exchangers.

DESCRIPTION: Seawater heat exchangers are plagued by fouling, such as particulate and biological film formation, during operation. Fouling of heat exchangers is a serious and long-standing problem that can result in decreased heat transfer efficiency, higher resistance to fluid flow, increased energy consumption, decreased heat exchanger lifetime, and increased downtime necessary to replace or clean fouled parts. Biological fouling is the accumulation of microorganism, plants, algae or animals on the interior of the tube and is the type of fouling most experienced. Turf-like algae growths are increasingly found when operating in warm seawater environments. The Navy currently uses a combination of periodic chlorination and periodic seawater flush to mitigate fouling in titanium seawater heat exchangers. Seawater flushing at velocities of 3 m/s is sufficient to remove most particulates. However, electrolytic chlorinator systems used to remove biological fouling are expensive, difficult to maintain, and ineffective in warm water.

This topic seeks new passive or active environmental-friendly fouling mitigation techniques that would prolong heat exchanger performance and availability. Potential solutions include, but are not limited to, active controls that could periodically scrub small groups of tubes using high flow rates; head re-design to eliminate flow dead zones; and the application of novel coatings on fouling-prone areas within heat exchanger to prevent adhesion of particles or microbes with minimum degradation in heat transfer.

PHASE I: Develop concepts to mitigate biological fouling in seawater heat exchangers. Validate feasibility by modeling and subscale demonstration at seawater temperatures up to 38 °C. Prepare a Phase II plan.

PHASE II: Develop a prototype system capable of eliminating biological fouling in a representative titanium shell and tube heat exchanger sized for a 200 refrigeration ton chiller. Evaluate performance in a relevant seawater environment (warm water port). Validate and expand analytic models (developed in Phase I) that must comply with Navy's Hazardous Material Control and Management program.

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 EMI. Explore dual-use applications in seawater cooled power plants, as well as commercial marine vessels.

REFERENCES:

1. Satpathy K.K. et al. "Biofouling and its control in seawater cooled power plant cooling water system - a review." Nuclear Power, IntechOpen, DOI: 10.5772/9912 (2010).
https://www.researchgate.net/publication/221909115_Biofouling_and_its_Control_in_Seawater_Cooled_Power_Plant_Cooling_Water_System_-_A_Review
2. Fan, S. et al. "A state-of-the-art review on passivation and biofouling of Ti and its alloys in marine environments." Journal of Materials Science & Technology 34, 2018, pp. 421–435,.
<https://www.sciencedirect.com/science/article/pii/S1005030217302840>

3. Mamroth, A., Frank, M., Hollish, C., Brown, R. and Simpson, M.W. “A Hybrid Marine Air Conditioning Plant Model for Condition-Based Maintenance Diagnostics.” Proceedings of ASNE Advanced Machinery Technology Symposium (2020).

4. Navy Safety and Occupational Health (SOH) Program Manual for Forces. OPNAVINST 5100.19F. <https://www.secnav.navy.mil/doni/Directives/05000%20General%20Management%20Security%20and%20Safety%20Services/05-100%20Safety%20and%20Occupational%20Health%20Services/5100.19F.pdf>

KEYWORDS: Thermal Management, Heat Exchangers, Biofouling, Coatings

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Develop a prototype system that leverages the current state-of-the-art in multimodal input/output (I/O) methodologies to control unmanned systems (UxS) at varying levels (i.e., from issuing broad tasking down to teleoperation) and to monitor status (i.e., see video from cameras, position on a map). This system will enable a graceful transition between Human-computer Interaction (HCI) technologies, including gesture [Ref 1], speech, eyetracking [Ref 2], manual control, teleoperation, and more [Ref 3]. This transition can be initiated by the user or by the system itself detecting environmental or operational circumstances.

DESCRIPTION: A number of unmanned systems are being deployed to the Fleet and Force, including Naval Special Warfare (NSW) operators and U.S. Marine Corps small unit leaders. UxS can provide enhanced command & control (C2) and Intelligence, Surveillance, and Reconnaissance (ISR) capabilities, but there remains an open question on how to effectively control these systems. There are many use cases that demand different control schemes. For example, if remotely surveilling a building, direct teleoperation and monitoring through a tablet may suffice. However, in room clearance operations, the warfighter's hands will be occupied, so a speech interface and monitoring through a HUD is ideal. In yet another scenario, eyetracking or a gestural interface may be required. How to gracefully transition between these interaction modalities is unknown, and human-machine teaming is ripe for the integration of interface technologies to support a variety of operations.

One solution is to draw from the communications domain, which uses the Primary, Alternate, Contingency, and Emergency (PACE) model to allow for failover between communications systems. While human-machine interfaces cannot be ranked like communications protocols (e.g., by available bandwidth), there are advantages and disadvantages to different input (control) methods (teleoperation, eyetracking, speech, gestures, etc.) and output (monitoring) methods (weapon-attached screen, tablet, HUD, etc.). It is critical to understand the operator- and environment-centered circumstances that lend themselves to specific I/O methods working better than others.

This SBIR topic seeks to integrate existing human-machine interface technologies, minimize the amount of extra equipment needed to be carried by the warfighter, and develop a prototype system that allows for graceful transition between I/O methodologies based on a number of factors (user preference, operational circumstances, system recommendation, etc.). The system should be easy to use by the warfighter and provide flexible interaction modalities with UxS(s) as missions and situations rapidly change.

PHASE I: Determine requirements for how warfighters will use companion UxS(s) in missions, focusing on NSW and Marine Corps squad leader use cases. Collect information on various I/O methodologies and determine how they can be integrated into a holistic UxS control and monitoring system. Phase I deliverables will include: (1) use cases for warfighter and UxS teaming, (2) identification of control and monitoring systems for integration, (3) an understanding of the pros and cons of each I/O modality and associated human factors principles for design, and (4) mock-ups or a prototype of the system.

The Phase I Option, if exercised, should also include the processing and submission of all required human subjects use protocols, should these be required. Due to the long review times involved, human subject research is not allowed during Phase I. Phase II plans should include key component technological milestones and plans for at least one operational test and evaluation, to include user testing.

PHASE II: Develop a prototype system based on Phase I effort and conduct a field demonstration between a user and UxS(s). Specifically, the target audience (e.g., NSW operator or Marine Corps squad team leader) will be identified, along with a relevant UxS(s). Technologies identified in Phase I will be integrated with the user's standard equipment. Additional software will be created to manage the various I/O modalities, allowing for smooth user-initiated transition or software-automated transition based on detection of environmental or operator workload circumstances. System design will occur in an iterative fashion, with multiple user group interactions feeding back into development. Phase II deliverables include: (1) a working prototype of the system that a user is able to control and switch between modalities, and (2) a field demonstration of a complete or near-complete system to users and stakeholders with users completing a variety of scenarios, easily switching between input (control) and output (monitoring) methods.

PHASE III DUAL USE APPLICATIONS: Support the customer (NSW or Marine Corps) in transitioning the technology for use. Further develop the software and hardware system for evaluation to determine its effectiveness in the field for NSW or Marine Corps scenarios. As appropriate, focus on broadening capabilities and commercialization plans.

Commercially, there are many explorations of different human-machine interface modalities. Companies are developing augmented reality technologies (e.g., Microsoft and Apple), eyetracking (e.g., Tobii and some Samsung Galaxy phones), speech interfaces (e.g., Amazon, Google, and Apple), and gesture control (e.g., Google Pixel phones, Microsoft Kinect). Development of affordable, scalable, and non-proprietary human-machine interfaces is not a current priority in the private sector. However, as new phones, tablets, smart watches, wireless earbuds, AR glasses, and more come to market, the commercial world will need to develop an integrated control scheme to manage these devices without overwhelming the user. Therefore, technology developed will have broad application to the private sector.

REFERENCES:

1. Cauchard, J. R., Tamkin, A., Wang, C. Y., Vink, L., Park, M., Fang, T., & Landay, J. A. (2019, March). Drone. io: A Gestural and Visual Interface for Human-Drone Interaction. In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 153-162). IEEE.
2. Yuan, L., Reardon, C., Warnell, G., & Loianno, G. (2019). Human gaze-driven spatial tasking of an autonomous MAV. *IEEE Robotics and Automation Letters*, 4(2), 1343-1350.
3. Calhoun, G. L., Draper, M. H., Guilfoos, B. J., & Ruff, H. A. (2005). Tactile and Aural Alerts in High Auditory Load UAV Control Environments. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 49(1), 145-149.

KEYWORDS: Human-computer Interaction, Eyetracking, Speech Interfaces, Gesture Interfaces, Augmented Reality

RT&L FOCUS AREA(S): Network Command, Control and Communications, Nuclear
TECHNOLOGY AREA(S): Information Systems, Ground Sea, Materials

OBJECTIVE: Develop a Buoyant Cable Antenna (BCA) handling/transfer mechanism that can provide sufficient pushing and pulling force to cabled antennas at depth while limiting wear and stress to the cable.

DESCRIPTION: The submarine fleet within the U.S. Navy has been successful in a wide range of missions. For many of these missions, success or failure depends on the submarine's ability to be stealthy and remain undetected by opposing forces. While submerged, maintaining stealth when communicating can be done through the use of towed horizontal floating wire RF antennas. However, new antenna and situational awareness sensor designs are not compatible with current floating wire antenna submarine deployment mechanisms. Furthermore, current antenna designs rely on deployment mechanisms designed in the 1960s and 1970s. Technological advancements in material and manufacturing processes since the 1960s create an opportunity to design a newer innovative handler with increased capability. Newer mechanical developments and innovations, such as linear transaction drives, have been proven for use in similar applications on other nations' submarines and may offer improvements over existing push/pull pulley systems.

The goal of this SBIR topic is to produce a BCA transfer mechanism capable of deploying, towing, and retrieving a BCA at speed and depth with minimal wear on the BCA. Minimal wear is considered as 2000 feet of BCA is deployed and retrieved 40 or more times. The size and layout shall be suitable to enable replacement of the existing submarine system. The final product will be a BCA transfer mechanism that is able to provide sufficient pushing and pulling force while limiting cable stress and enabling the use of additional sensors. The effort shall demonstrate the following capabilities:

- Demonstrate the BCA transfer mechanism's capability of deploying, towing and retrieving a BCA with cable diameter between 0.85 to 0.95 inches. A sample cable can be provided by the Government upon contract award.
- Demonstrate the transfer mechanism can deploy and retrieve a BCA at a speed of 0 to 20 feet per minute or faster.
- Demonstrate the transfer mechanism can generate a threshold minimum pulling force of 2000 pound-force (lbf) on the cable.
- Demonstrate the transfer mechanism can generate a threshold minimum pushing force of 150 lbf on the cable.
- Demonstrate the mechanism does not bend the BCA at less than 8.3 inches of bending radius in order to limit mechanical stress and wear on BCA.
- Demonstrate the handling system will fit within the space and arrangement constraints of the legacy system. Approximate available space for system are shown in Table One.

Table One

Transfer Mechanism: Height (in) 33; Width (in) 18; Depth (in) 14; Vol (cu. Ft.) 4.8; Weight (lbs) 400
Cable Stowage Reel: Height (in) 47; Width (in) 42; Depth (in) 38; Vol (cu. Ft.) 43.4; Weight (lbs) 950

- Demonstrate the transfer mechanism's housing can sustain internal water pressures up to 900 psi.
- Demonstrate the transfer mechanism can be primarily driven using existing ships hydraulic system.

PHASE I: Conduct a feasibility study and develop concept designs for a BCA transfer mechanism. Identify BCA handling system design specifications that are critical for meeting functional requirements.

Compare and contrast concept designs with the legacy transfer mechanism. Verify through modeling and simulation that the BCA transfer mechanism will enable the deployment, tow, and retirement of the antenna at a range of operating speeds and depth. Define the process for building the antenna transfer mechanism. Develop prototype plans for Phase II.

PHASE II: Develop or optimize the prototype antenna transfer mechanism identified in Phase I. The final antenna transfer mechanism should meet the functional requirements while staying within the bounds of external requirements such as ship spec requirements, size, etc. Conduct benchtop and land-based tests. Compare simulated results to benchtop and land-based results to demonstrate credibility of the model. Work performed during the Phase II will not be classified, but a DD254 will be required because the performer will need to be able to review classified technical drawings of the current Navy system.

PHASE III DUAL USE APPLICATIONS: Deliver final BCA transfer mechanism to a Navy facility in sufficient quantity for testing with buoyant cable antenna. Support Government laboratory testing and Environmental Qualification Testing.

Commercial uses of this antenna transfer mechanism could include: (1) undersea communications cable deployment/ repair, and (2) undersea oil exploration and related equipment.

REFERENCES:

1. Rivera, David and Bansal, R. "Towed Antennas for US Submarine Communications: A Historical Perspective." IEEE, August 2004. <https://ieeexplore.ieee.org/document/1296142>.
2. Rivera, David and Bansal, R. "Submarine Towed Communication Antennas: Past, Present, and Future." IEEE, August 2002. <https://ieeexplore.ieee.org/document/959753>.

KEYWORDS: Antenna Deployment, VLF, VHF, Communications, Stealth, Buoyant Cable Antenna, BCA

N202-135

TITLE: Model Based Systems Engineering for Tactical Data Link Systems

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

TECHNOLOGY AREA(S): Information Systems, Materials, 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: Develop and demonstrate ability to identify, aggregate, and analyze distinct data types and formats to enhance the decision-making process during the technology assessment and trade-offs, design, development, testing, and qualification phases of tactical data link systems using Model Based Systems Engineering (MBSE).

DESCRIPTION: The goal of this SBIR topic is to develop a Systems Modeling Language (SysML) digital twin system model of the Multi-Functional Information Distribution System (MIDS) Joint Tactical Radio System (JTRS) terminal configurations. The MIDS Program Office (MPO) is interested in significantly improving and expanding its engineering support infrastructure to enable deployment of more efficient, agile, and resilient tactical data links systems models to expedite capability to the fleet. The MPO intends to implement a Model-Based System Engineering approach for all engineering activities that uses models as an integral part of the technical baseline including requirements generation and validation, analysis, technology trade-offs, design, implementation, and verification of a capability, system, product and/or technology throughout the acquisition lifecycle. A model-based system will enable unprecedented levels of systems understanding that can be achieved through integrated analytics, tied to a model-centric technical baseline and will support new DoD acquisition initiatives to expedite warfighting capabilities to the fleet [Refs 1, 2, 3].

Implementing this type of capability would expedite correlation of relevant technical data, software, information, knowledge and technology trade-offs to enhance tactical data link development. This environment would provide substantial acceleration of development of solutions and technology transition resulting in reduced time and significant cost reduction of critical capabilities to the warfighter.

Work produced in Phase II will likely 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 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. NAVWAR will process the DD254 to support the contractor for personnel and facility certification for secure access.

PHASE I: Define solution(s) to develop digital twin system model of the MIDS JTRS terminal configuration. Outline model elements, including characterizing behavior, structure, requirements, and

parametrics, that further refine trades in developing tactical data link systems. Solution must specify data storage and computational requirements and will identify existing DoD capabilities that may contribute to the desired end-state capability, identify capability gaps and establish a methodology to deliver needed capability. Information absorption and temporal requirements will be baselined during Phase I. Propose model simulations are strongly encouraged and could take several forms such as augmentations/plugin to existing SysML tools. Partnership with MIDS prime vendors is encouraged to help understanding of MIDS design and potential models they use. Partnership with NAVWAR 5.0 Digital Engineering Transformation Division is encouraged. Phase I will be UNCLASSIFIED, and the contractor will not require access to any classified data. Develop a Phase II plan.

PHASE II: Develop a prototype model based on the learning of Phase I effort. Validate and demonstrate the proposed data analytic capability leveraging existing DoD tactical data link infrastructure. Demonstrate the prototype system using MBSE tools identified in Phase I. Include, at a minimum, demonstration of a prototype tool or methodology on a small system(s) application that is representative of a portion of the tactical data link infrastructure, and documentation describing anticipated use of the tool. Ensure model adherence to SysML and Unified Architecture Framework (UAF) specifications, as well as eXtensible Markup Language (XML) Metadata Interchange (XMI) Standard, is desired. Endstate should ensure model can be used to inform tactical data link analysis including (but not limited to) requirements, impact, trade-off, behavior, interoperability or data flow.

The expected TRL for this project is 5 to 6. Partnership with MIDS prime vendors is encouraged, but not required. Partnership with NAVWAR 5.0 Digital Engineering Transformation Division is encouraged. It is likely that the work under this Phase II effort will be classified (see Description section for details). Though Phase II work may become classified, the proposal for Phase II work will be UNCLASSIFIED. If the selected Phase II contractor does not have the required certification for classified work, the related DON program office will work with the contractor to facilitate certification of related personnel and facility.

PHASE III DUAL USE APPLICATIONS: Mature the model and extend use to multiple data link centric platforms within the Navy and private sector. Support or license the final product (s) and transition to the Government. The technology will have application throughout government and industry. Performers from component developers (e.g., Intel, Texas Instrument, etc.) to system integrators (e.g., LM, Boeing, BAE, etc.) could use these models to reduce costs in data link development. Partnership with prime vendors is encouraged, but not required. Navy seeks selected vendor to support transitioning of MBSE solution(s) across the Services.

REFERENCES:

1. Shortell, Thomas M., editor. "INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities 4th Ed."
2. Office of the Deputy Assistant Secretary of Defense for Systems Engineering. "Best Practices for Using Systems Engineering Standards on Contracts for DoD Acquisition Programs." April 2017. <http://acqnotes.com/wp-content/uploads/2014/09/OSD-Guide-to-Best-Practices-Using-Engineering-Standards-2017.pdf>
3. Kobryn, P., Tuegel, E., Zweber, J., and Kolonay, R. "Digital Thread and Twin for Systems Engineering: EMD to Disposal." 55th AIAA Aerospace Sciences Meeting, 9-13 January 2017, p. 11. <https://arc.aiaa.org/doi/abs/10.2514/6.2017-08764>. Wang, Gang, et al. "Big data analytics in logistics and supply chain management: Certain investigations for research and applications." International Journal of Production Economics 176, 2016, pp, 98-110. <https://ideas.repec.org/a/eee/proeco/v176y2016icp98-110.html>

KEYWORDS: Model Based Systems Engineering, MBSE, SysML, Digital Twin, Tactical Data Links, MIDS, XMI

N202-136 [Navy has removed topic N202-136 from the 20.2 SBIR BAA]

RT&L FOCUS AREA(S): Hypersonics
TECHNOLOGY AREA(S): Materials

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 noncontact measurement techniques, or sensor embedding procedures in candidate hypersonic material specimens whose size scale is on the order of millimeters, and high throughput (100s of test per day) measurement protocols under candidate hypersonic ablative shock boundary conditions.

DESCRIPTION: Hypersonic materials operate in extreme environments of pressure and temperature. Design of new materials and structures for hypersonic applications, as well as testing of existing materials and structures requires detailed examination of critical feature effects as a function of environmental variables. Per test cost for current materials runs into millions, with throughputs of approximately 5-10 specimen per day (e.g., Arc Jet tests). Such large-scale tests also fail to capture the effect of material specific, small scale features. Having a capability to understand/examine key feature effects as a function of these extreme environments utilizing extremely low volume sample sizes would allow for high throughput material testing (~300 tests per day) at low cost enabling more rapid material development. This research will increase mission capability and performance, while decreasing lifecycle costs by allowing for accurate and rapid evaluation of new and existing hypersonic/extreme environment materials and designs.

The desired outcome of this work is the development of a system to measure material surface pressure, stress, and temperature under shock loading and at laser ablation temperatures to examine effectiveness of hypersonic materials under realistic plasma, flow, and thermal shock conditions with micrometer scale resolution. This can be accomplished via noncontact or embedded, preferably passive, sensors embedded in hypersonic materials to predict material surface pressure in realistic flight conditions. The developed system must have a robust calibration technique and small scale spatial and temporal resolution, preferably down to the micrometer and microsecond scale. Ultimately, the sensors and materials to be examined must be evaluated in realistic flow conditions.

The outcomes of the proposed work are:

- 1) Non-contact or passive (wireless) embedded sensors, which are inexpensive for remote monitoring of surface pressure, temperature, and stress in hypersonic materials subjected to realistic flow conditions;
- 2) Calibration of sensors for predicting surface pressure during in-situ measurements; and
- 3) Wind-tunnel measurements to put calibrated sensors in realistic flow conditions for evaluating sensor performance at various flow conditions that are appropriate to the hypersonic regime.

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 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: Conduct a feasibility study, focusing on non-contact and/or embedded passive sensors. Demonstrate proof of concept of the measurement system in a laboratory environment using laser ablation or other means of generating representative temperatures, stress, etc. High throughput capability should be demonstrated (order of magnitude increase over state-of-the-art) with a clear path to increase the number of tests per day by approximately two orders of magnitude over the current state-of-the-art, while also demonstrating the improved spatial and temporal measurement resolution. 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: Produce a prototype system capable of high throughput (approximately two orders of magnitude increase over current state of the art) measurements, which is achieved via a non-contact or embedded passive sensor array, including improved spatial and temporal resolution. Demonstrate the prototype in a hypersonic flow environment. Correlate the results with current state-of-the-art test results. Prepare a Phase III development plan to transition the technology for Navy use and potential commercial 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: High throughput, high fidelity testing of high temperature materials will allow for materials and structures to be evaluated more rapidly and at lower cost. Other systems, such as those associated with space propulsion could benefit from this type of high throughput testing.

REFERENCES:

1. Olokun, T., Prakash, C., Men, Z., Dlott, DD, and Tomar, V. "Examination of Local Microscale-Microsecond Temperature Rise in HMX-HTPB Energetic Material Under Impact Loading." JOM, October 2019, Volume 71, Issue 10, pp. 3531-3535. DOI: 10.1007/s11837-019-03709-z
2. Dhiman, A., Sharma, A., Shashurin, A., and Tomar, V. "Strontium Titanate Composites for Microwave-Based Stress Sensing." The Journal of the Metals, Minerals, and Materials Society, Vol 70(9), pp. 1811-1815.
<https://web.a.ebscohost.com/abstract?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=10474838&AN=131260349&h=3jz88ui1kQUPOQDuDgvfO%2b9G8MwOEmROzOA313ny5SZmKbUeCLq2RBw4UINYf8Tjqcs2fecFbTrQkw7IIUouQQ%3d%3d&crI=c&resultNs=AdminWebAuth&resultLocal=ErrCrINotAuth&crIhashurl=login.aspx%3fdirect%3dtrue%26profile%3dehost%26scope%3dsite%26authtype%3dcrawler%26jrnl%3d10474838%26AN%3d131260349>
3. "Hypervelocity testing at 600 shots/year." NASA.
https://www.nasa.gov/centers/wstf/testing_and_analysis/hypervelocity_impact/index.html

KEYWORDS: High Throughput Testing, Hypersonic Materials, Embedded Sensing, Non-contact Sensing, Extreme Temperature Environments, Ablative Shock Boundary Conditions

N202-138 [Navy has removed topic N202-138 from the 20.2 SBIR BAA]

RT&L FOCUS AREA(S): Hypersonics
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: Create an optimization/sensitivity model that utilizes kill probability as the basis for assessment of alternative hypersonic system technologies.

DESCRIPTION: Hypersonic vehicles (HV) are designed to travel at high speeds pursuing deeply protected targets and seeking to impact them with sufficiently high energy. Thus, the Probability of Kill for a hypersonic weapon depends on both the ability to arrive at the target and to sufficiently damage it. Mathematically, the Probability of Kill (P_k) for a HV can be expressed as the product of the Probability of Arrival (P_a) multiplied by the Probability of Damage (P_d): $P_k = P_a * P_d$. The main challenge for developing an effective HV is that there are many vehicle performance and mission scenario parameters that influence P_k . Innovation is needed to develop a 'system of systems' analysis capability that models the many interdependent components and sub-components of P_k as a function of new technologies on the HV and then optimizes the family of technologies that maximizes P_k across relevant mission sets. The desired system of systems model will provide a framework to capture P_a and P_d under a variety of technology infusion scenarios and integrate these into assessments into the optimization of P_k of a new HV. The prototype framework should leverage both low- and high-fidelity models to robustly estimate the cost-benefit proposition (on P_k) from the injection of new technologies into the HV development and justify the robustness of the estimates with extensive sensitivity analysis.

Estimating the P_a hinges on the ability to capture the behaviors and physical limitations of the HV itself, the supporting role of other blue-force systems, and the efficacy of any non-target red-force systems and their behaviors. In uncontested scenarios, this may be simply a function of time and geometry; however, in more complex scenarios that represent real-world scenarios, producing such a model requires incorporating capabilities of multiple interdependent systems. Estimating the P_d can be accomplished by a statistical model obtained by aggregating high-fidelity models and inputs. P_d can be calculated separately from the P_a by capturing the state information of the HV and pairing that with accepted models of threat systems. However, for any given mission and any given time, the state of HV at impact, again, is dependent on the blue-force support systems and the effect from red-force counter systems.

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 need be, 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 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 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: Define and develop a conceptual framework for calculating P_k of HV based on modeling probability of arrival and probability of damage.

Develop a concept for a system of systems modeling and simulation capability that can be flexibly and iteratively refined to include models of increasing fidelity blue and red force assets, including new and novel technologies within the major systems of HVs.

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: Deliver P_d models and P_A models that can be used to determine P_k for HVs. This will provide a framework to build a model for P_k that can be used to evaluate more complex systems. Validate the subsequent P_k results by comparison to field test data from HV flights.

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: Deliver an integrated toolset that assesses both P_d and P_A by integrating a representative set of low- and high-fidelity models of interest. Demonstrate P_k for real world scenarios by incorporating operational model HV and system of systems.

The inherent functionality of the proposed analysis toolset would be applicable to any complex hypersonic vehicle application. For example, the design of planetary entry systems requiring precise targeting for landing would benefit from these innovations.

REFERENCES:

1. Ezra, Kristopher L., DeLaurentis, Daniel A., Mockus, Linas and Pekny, Joseph F. "Developing Mathematical Formulations for the Integrated Problem of Sensors, Weapons, and Targets." Journal of Aerospace Information Systems, Vol. 13, No. 5, 2016, pp. 175-190.
<https://arc.aiaa.org/doi/full/10.2514/1.I010372>
2. Grant, Michael J., and Braun, Robert D. "Rapid indirect trajectory optimization for conceptual design of hypersonic missions." Journal of Spacecraft and Rockets 52.1, 2014, pp. 177-182.
<https://arc.aiaa.org/doi/full/10.2514/1.A32949>
3. Bogdanowicz, Zbigniew R., et al. "Optimization of weapon–target pairings based on kill probabilities." IEEE transactions on cybernetics, 43.6, 2012, pp. 1835-1844.
<https://ieeexplore.ieee.org/document/6392482>

KEYWORDS: Probability of Kill, Probability of Damage, Probability of Arrival, Hypersonic Vehicles, System of Systems Analysis, Mission Effectiveness, Technology Assessments, Vehicle Design

N202-140 [Navy has removed topic N202-140 from the 20.2 SBIR BAA]

N202-141

TITLE: Investigate the use of Discrete Patterned Roughness for Turbulent Transition Control in a Hypersonic Boundary Layer

RT&L FOCUS AREA(S): Hypersonics

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: Model and investigate the use of discrete patterned roughness for turbulent transition control with rough surface conditions that result from manufacturing, or wear and ablation during hypersonic flight.

DESCRIPTION: Discrete patterned roughness has been successful in suppressing laminar-turbulent transition on hypersonic lift-generating configurations involving cross-flow. In these cases, the surfaces have been hydrodynamically smooth. Experiments are needed to evaluate the effect of rough surfaces on the transition control. This should involve experiments in multiple (at least two) quiet hypersonic wind tunnels. Test articles would be lift-generating geometries in which a cross-flow instability is the dominant mechanism of turbulent transition. These articles would include a number of documentable surface roughness conditions, including a baseline smooth surface. The roughness descriptions will be used in simulations of boundary layer turbulent transition with the experiments providing validation. These experiments will document the sensitivity of transition Reynolds number and the level of discrete roughness transition control on the background roughness. In the event of a reduction in transition control, approaches to overcome this should be proposed.

Wind tunnel experiments at Mach 3.5 and 6.0 have demonstrated the ability of patterned discrete roughness to delay turbulence transition on lifting bodies where the dominant mechanism is through a cross-flow instability and is applicable to circular cones at angles of attack and elliptic cross-section cones such as the HiFiRE-5 (Hypersonic International Flight Research Experimentation Program) design. The approach is based on seeding less-amplified (subcritical) stationary cross-flow modes that suppress the growth of the more-amplified (critical) cross-flow modes, and thereby delay transition. Experiments on circular cones at angles of attack have increased the transition Reynolds number by as much as 40%. These experiments have been in idealized flows without extreme surface heating or ablation. The model surfaces were also highly polished so that the discrete roughness height or depth could be extremely small ($O(40\mu\text{m})$). For transition control, the necessary roughness height or depth will depend on the background surface roughness. A more critical scale is the spacing between the discrete roughness that determines the spanwise wavenumber of the excited subcritical cross-flow modes. The background surface roughness spectrum will therefore be a factor.

Given the number of benefits of delaying transition on hypersonic vehicles, and the successful demonstrations of this technology, investigation into realistic flight geometries with surface roughness that takes into account wear and ablation is needed. This would involve wind tunnel experiments in multiple quiet hypersonic tunnels. The surface roughness of the test articles should range from a baseline smooth ($O(40\mu\text{m})$) surface to varying degrees of distributed roughness.

Descriptions of the roughness could likely come from surface impressions of past flight test vehicles, or possibly surfaces generated on test articles placed in high-enthalpy hypersonic facilities. In all cases, the roughness needs to be quantified through highly resolved 3-D surface measurements. The roughness descriptions would be used in simulations that predict turbulence transition and will be validated through comparisons to the experiments. Ultimately for practical implementation, the sensitivity of the discrete roughness transition control on the level of background roughness needs to be determined. In the event that a reduction in transition control is observed, approaches that overcome the reduction need to be investigated.

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 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 an initial concept design of a model geometry with cross-flow dominated laminar-turbulent transition and the generation of surface roughness representing pre-flight and post-flight conditions using a smooth surface to provide a baseline condition. Fabricate a model of a scale that will operate within the quiet zone of at least two quiet hypersonic wind tunnels. Employ wind tunnel conditions that are sufficient to achieve turbulent transition on the model, and roughness that is interchangeable, with documented characteristics.

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: Fully develop a model for the effectiveness of discrete roughness to suppress turbulent transition and ensure the validation of test articles in wind tunnel tests that will involve a test article that is large enough to provide better measurement of spatial resolution and reduce edge effects. Use the quantitatively same background surface roughness from Phase I. For the different roughness cases, perform experiments that measure the turbulent transition location, verify that the mechanism of transition involves a cross-flow instability, and includes both surface visualization and off-wall measurements in 3-D space within the boundary layer. With the added spatial resolution of the larger model, place special emphasis on off-wall measurements within the boundary layer. Specifically focus experiments on interaction between stationary and traveling cross-flow modes, with the latter possibly energized by the higher disturbance levels produced by the roughness. Use these results to form the basis for the design of discrete roughness model to suppress turbulent transition.

In addition to the experiments, develop simulations that are intended to be an analog to the wind tunnel experiments. Ensure that the simulations' initial conditions match the experimental conditions, and include descriptions of the background roughness from Phase I. Compare the results of the simulations directly with those in the experiments. Assuming experimental validation of the simulations, use it to further optimize the discrete roughness transition control. Prepare a Phase III development plan to transition the technology for Navy use and potential commercial 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: Conduct necessary qualification testing of the laminar-transition control method to merit further investment and consideration for military HV platforms. Work together with an OEM (original equipment manufacturer) to develop a business plan and seek necessary investment to support the product/process/service for the OEM military provider. This effort may have application to reentry vehicles operated by NASA or other organizations in addition to vehicles operating at trans-sonic and supersonic velocities.

REFERENCES:

1. Corke, T.,A.,E and Semper, M. "Control of stationary cross-Flow modes in a mach 6 boundary layer using patterned roughness." J. Fluid Mech., 856, 2018, pp. 822-849. DOI: <https://doi.org/10.1017/jfm.2018.636>
2. Schuele, C.Y. Corke, T. and Matlis, E. "Control of Stationary Cross-Flow Modes in a Mach 3.5 Boundary Layer Using Patterned Passive and Active Roughness." J. Fluid Mech., 718, 2013, pp. 5-38. DOI: <https://doi.org/10.1017/jfm.2012.579>

KEYWORDS: Hypersonic Vehicles, Laminar-Turbulent Transition, Transition Control, Surface Roughness, Wind Tunnel, Transition Reynolds Number

N202-142 [Navy has removed topic N202-142 from the 20.2 SBIR BAA]

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

TECHNOLOGY AREA(S): Materials

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 novel compact and inexpensive plasma-based widely tunable frequency impedance elements (plasma switches) and antennas capable of sustained high-power operation in contested/denied electromagnetic (L- and S-bands) environments.

DESCRIPTION: In the increasingly contested electromagnetic environment, Navy communication and guidance systems must have the capability to rapidly close the transmission “frequency window” when faced with electromagnetic threats, such as jamming or high-power microwave (HPM) weapons. Additionally, when faced with high-power electromagnetic threats, the communication and guidance systems should have the capability of being rapidly tuned to a different frequency outside the frequency range of the threat.

While various technologies, including those based on semiconductors, ferrites, mechanical devices, etc., have been proposed to address these needs, the devices based on those technologies are bulky, have generally high insertion losses, and have either slow responses or are easily damaged when operating at high power levels.

Devices based on low-temperature plasmas are promising for tunable high-power limiters and impedance elements. Plasma discharges can be turned on and their properties can be changed rapidly, on a nanosecond time scale. Insertion losses of such devices can be very low. Commercially available sealed plasma devices are also compact and inexpensive and have been shown to be robust in prolonged operation at Very High Frequency (VHF) to gigahertz (GHz) range frequencies; however, the characteristics of the gas mixtures are proprietary, and limited to a few commercially available sources with limited information on the plasma characteristics. The electromagnetic properties of plasma discharges are quite rich, combining resistive, inductive, and capacitive behavior, and those properties can be varied widely by, e.g., controlling the excitation waveform and power, applying a bias, and placing the plasma discharge in a resonant structure. Research aimed at understanding, characterizing, and evaluating such behavior is critical for the development of plasma-based limiters and switches, focused on improving performance and flexibility in a contested Radio Frequency (RF) environment.

Based on previous research and development (References 1-3), the plasma-based switches and antennas should be frequency-tunable in a wide range (over an octave) and operate at a power level of over 100 Watts (W), but capabilities that have not yet been demonstrated. Radiation at this power level would enable multiple use-cases relevant to Navy operations.

The Phase II effort will likely 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 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 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 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: Determine the technical feasibility of a concept by designing (a) an octave-tunable plasma switch capable of operation at 100 W, and (b) an octave-tunable antenna and/or antenna array that would effectively utilize such a switch. Begin characterization of radiation properties at this power level within the tunable frequency range.

The Phase I Option, if exercised, will include the initial design specifications and identify risks and propose a plan to mitigate the risks in Phase II. Prepare a Phase II plan.

PHASE II: Develop, characterize, and demonstrate a frequency-tunable plasma antenna and/or antenna array operating above 100 W and with a plasma switch that enables an octave frequency tuning at all power levels. Develop and validate a model to describe the plasma behavior in these devices. Develop optimal designs for both the switch and antenna using the model, given relevant use cases. Characterize the device lifetime under extreme thermal and shock conditions expected in applications. Prepare a Phase III development plan to transition the technology for Navy use and potential commercial 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: Refine the designs developed in Phase II. Work with the Navy on integration of the devices into the application platforms and testing their performance in the relevant conditions. Based on the integration and testing, further refine the designs.

The tunable high-power plasma switches and antennas are expected to be applicable for non-military applications such as cell phone towers.

REFERENCES:

1. Semnani, A., Peroulis, D. and Macheret, S. "Plasma-Enabled Tuning of a Resonant LC Circuit." IEEE Transactions on Plasma Science, Vol. 44, No. 8, Part 2, 2016, pp. 1396-1404. <https://ieeexplore.ieee.org/document/7516629>
2. Semnani, A., Peroulis, D. and Macheret, S. "A High-Power Widely Tunable Limiter Utilizing an Evanescent-Mode Cavity Resonator Loaded With a Gas Discharge Tube." IEEE Transactions on Plasma Science, Vol. 44, No. 12, 2016, pp. 3271-3280. <https://ieeexplore.ieee.org/document/7756341>
3. Semnani, A., Macheret, S. and Peroulis, D. "A Quasi-Absorptive Microwave Resonant Plasma Switch for High-Power Applications." IEEE Transactions on Microwave Theory and Techniques, Vol. 44, No. 12, May 2018, pp. 1-9. doi: 10.1109/TMTT.2018.2834925

4. Khomenko A. and Macheret, S. “Capacitively coupled radio-frequency discharge in alpha-mode as a variable capacitor.” Journal of Physics D: Applied Physics, Vol. 52, No. 44. <https://doi.org/10.1088/1361-6463/ab3367>

KEYWORDS: Rapidly Tuned Impedance Elements, Plasma, Plasma Discharges, Plasma-based Switch, Plasma-based Limiter, Antennas, Antenna Arrays

RT&L FOCUS AREA(S): Hypersonics
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 physics-based model to predict trajectory instability of a long rod penetrating semi-infinite targets.

DESCRIPTION: There is an urgent need to develop a physics-based model to predict this trajectory instability. In the transition zone near the point of maximum penetration depth and the onset of the semi-hydrodynamic regime, projectiles were observed to bend and yaw violently without significant mass loss. While prior works exist to model the impact response in the transition zone [Ref 1], these studies typically focused purely on the penetration depth via semi-empirical methods.

The penetration depth of cylindrical projectiles into targets across a broad range of impact velocities typically exhibits three distinct regimes. At lower impact velocities, the projectile undergoes nearly rigid body penetration within the target. Towards the high end of the velocities in this regime, the maximum penetration depth is achieved. With further increasing striking velocities, the projectile begins to experience erosion and the penetration depth starts to saturate. This regime is known as the semi-hydrodynamic regime. At even higher velocities, the impact phenomenon becomes hydrodynamic where the projectile strength becomes practically negligible.

This phenomenon has been observed experimentally across a range of different target materials, including metals [Ref 2], geomaterials [Ref 3], and fluids [Ref 4], and across several different types of projectiles and shapes. This yawing and bending instability causes severe deviation from the desired trajectory, and severely limits projectile penetrating performance [Ref 2]. Stability and vibration dynamics models have long been established for slender rods moving axially in fluid [Ref 5]. Depth of penetration models focused most on solid targets.

The proposed model aims to identify critical conditions and parameters resulting in this instability across different targets in order to optimize the penetrative capabilities of projectiles. The parameters of interest may include, but not be limited to, projectile aspect ratio, nose shape, velocity, and strength of materials that are interacting under conditions of different soil types or hardened materials, e.g., reinforced concrete.

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 need be, 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 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 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 physics-based model for long rod penetration. Identify critical conditions and parameters that affect long rod penetration into different soil types or hardened materials, e.g., reinforced concrete. Assess the viability of the model for long rod penetration to include mechanisms not inherent just in fluid flow or solid cavity expansion, such that the stability of the trajectory can be predicted, together with dominating parameters dictating the onset of instability. Compare the model prediction with typical penetration cases in this and subsequent phases to assess the feasibility of the model. 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: Model validation and critical condition determination. Design and conduct penetration experiments with flash X-ray sequence imaging for global trajectory response and Synchrotron X-ray high-speed imaging for local projectile-target interactions to validate the model. Simultaneously, document existing experimental data in literature and conduct numerical simulations on different semi-infinite target media to fine-tune the model and identify parameter critical ranges. Validate the model within the scope of the physical and numerical experiments and literature data, and that it is ready to be further developed into a design tool.

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: Develop the model into a predictive tool, together with the resulting stability criteria and critical parameters, for applications involving long-rod penetration into semi-infinite targets. Perform systematic penetration experiments to expand the model application range over a variety of projectile/target combinations. Ensure that the final product is an efficient, low-cost method of design projectiles and predicting their capabilities in penetrating various semi-infinite targets. Applications of the final product are not limited to defense applications, as the developed model may be extended to other fields such as pile-driving in civil engineering fields.

REFERENCES:

1. Chen, X. & Li, Q. "Transition from nondeformable projectile penetration to semihydrodynamic penetration." J. Eng. Mech., 2003, pp. 123-127. <https://www.scribd.com/document/439663186/Transition-From-Non-Deformable-Projectile-Penetration-to-Semi-Hydrodynamic-Penetration>
2. Piekutowski, A. J., Forrestal, M. J., Poormon, K. L. & Warren, T. L. "Penetration of 6061-T6511 aluminum targets by ogive-nose steel projectiles with striking velocities between 0.5 and 3.0 km/s." Int. J. Impact Eng., 23, 1999, pp. 723-734. [https://doi.org/10.1016/S0734-743X\(99\)00117-7](https://doi.org/10.1016/S0734-743X(99)00117-7)
3. Bivin, Y. K. & Simonov, I. V. "Mechanics of dynamic penetration into soil medium." Mech. Solids, 45, 2010, pp. 892-920. <https://www.semanticscholar.org/paper/Mechanics-of-dynamic-penetration-into-soil-medium-Bivin-Simonov/d8a935cc3e78d8c1f6847f93d6c8080c0c079596>

4. Roecker, E. T. & Ricchiazzi, A. J. “Stability of penetrators in dense fluids.” Int. J. Eng. Sci. 16, 1978, pp. 917-920. <https://www.sciencedirect.com/science/article/abs/pii/0020722578900757>

5. Gosselin, F., Païdoussis, M. P. & Misra, A. K. “Stability of a deploying/extruding beam in dense fluid.” J. Sound Vib. 299, 2007, pp. 123-142.
https://www.researchgate.net/publication/220004058_Stability_of_a_deployingextruding_beam_in_dense_fluid

KEYWORDS: Trajectory of Cylindrical Projectiles, Instability of Cylindrical Projectiles, Penetration of Hardened Targets, Physics-based Model, Semi-hydrodynamic Regime

RT&L FOCUS AREA(S): Hypersonics
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 hypersonic vehicle tracking system based on analysis of the wake turbulence and chemiluminescence.

DESCRIPTION: The distribution of observable markers in hypersonic wakes is the result of a complex interaction of body shape, chemical kinetics, and laminar-turbulent transition mechanisms. At hypersonic speeds in a gas, electrons and radiating species are generated by viscous heating that are entrained into the wake and are responsible for observable effects up to distances of hundreds or even thousands of body diameters. Clearly an understanding of the radiation signature of reentry vehicles is of fundamental importance to high-speed-flight research. During a brief period in the early 1960s, a number of experiments were conducted on this problem that involved performing both velocity measurements to characterize the turbulence development in the wake and spectroscopic techniques to identify the chemical kinetics of reacting species [Refs 1, 2, 3, 4, 5].

A general conclusion from this early body of work was that theoretical models were insufficient to adequately predict the structure of the wake and additional experiments were required. Improving the understanding of the laminar-to-turbulence transition, separation dynamics just behind the body, and turbulence statistics and structure in the wake was needed. Uncertainty in the estimations of enthalpy made it difficult to predict the temperature in the wake, which affects kinetics and generation of reacting species, crucial to the complete characterization of a hypersonic wake. A principle limitation was the unavailability of point-wise sensors with high-bandwidth sensitivity to mass-flux, temperature, and gas species with the required robustness and small measurement volumes.

Optical diagnostic tools do not provide point-wise capability and often involve path integration and are limited by the need for optical access. A new sensor is required that overcomes these limitations while providing both high bandwidth velocity and species detection capabilities. This sensor should be able to survive in harsh conditions involving exposed plasmas, an environment at temperatures of 1100 °C or greater, and high turbulence levels of 10% or greater in particulate-laden flows. The sensor should not require optical access, and should provide good spatial resolution with measurement volumes under 0.25 cu cm.

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 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 concept for velocity and gas mixture composition sensing capable of withstanding 1100 °C environments. Demonstrate the feasibility of the proposed sensor type and the packaging approach suitable to satellite payloads less than 1000 cu cm. Describe the manufacturing feasibility of the sensor and packaging necessary for commercialization efforts. Experimentally demonstrate feasibility of the proposed sensor at a laboratory scale at hypersonic Mach numbers. 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 characterize several full prototype devices in a low enthalpy hypersonic quiet tunnel and high enthalpy high Mach number flow field facilities. Prepare a Phase III development plan to transition the technology for Navy use and potential commercial 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 Navy use. Conduct necessary qualification testing of the device to merit further investment and consideration for military hypersonic vehicle platforms. Work together with original equipment manufacturer (OEM) to develop a business plan and necessary IP, and seek necessary investment to support the product/process/service for the OEM military provider. The use of chemiluminescence has potential applications in welding and plasma processing where the environments do not support physical interaction with the objects of interest.

REFERENCES:

1. Bayes, K., and Kistiakowsky, G.B. "On the Mechanism of the Lewis-Rayleigh Nitrogen Afterglow." *Chemical Physics*, 32, 4, March 1960, pp. 992-1000. <https://aip.scitation.org/doi/10.1063/1.1730909>
2. Hundley, R. "Air Radiation From Nonequilibrium Wakes of Blunt Hypersonic Reentry Vehicles." Memorandum RM-4071-ARPA, June 1964. https://www.rand.org/content/dam/rand/pubs/research_memoranda/2008/RM4071.pdf
3. Lees, L. "Hypersonic Wakes and Trails." *AIAA Journal* 2, 3, 1964, pp. 417-428. <https://arc.aiaa.org/doi/abs/10.2514/3.2356?journalCode=aiaaj>
4. Levensteins, Z., and Krumins, M. "Aerodynamic Characteristics of Hypersonic Wakes." *AIAA Journal* 5, 9, 1967, pp. 1596-1602. <https://arc.aiaa.org/doi/10.2514/3.4256>
5. Tanaka, Y., Innes, F., Jursa, A., and Nakamura, M. "Absorption Spectra of the Pink and Lweis-Rayleigh Afterglows of Nitrogen in the Vacuum-uv Region." *J. Chem. Phys.* 42, 4, 1965, pp. 1183-1198. <https://doi.org/10.1063/1.1696100>

KEYWORDS: Reentry Vehicles, Chemiluminescence, Hypersonic, Wake Turbulence, High Enthalpy, Laminar-turbulent Transition

N202-146 [Navy has removed topic N202-146 from the 20.2 SBIR BAA]

N202-147 [Navy has removed topic N202-147 from the 20.2 SBIR BAA]