

# VERSION 8

## DEPARTMENT OF THE NAVY (DON) 22.1 Small Business Innovation Research (SBIR) Proposal Submission Instructions

### IMPORTANT

- The following instructions apply to SBIR topics only:
  - N221-001 through N221-086
- The information provided in the DON Proposal Submission Instructions document takes precedence over the DoD Instructions posted for this Broad Agency Announcement (BAA).
- DON Phase I Technical Volume (Volume 2) page limit is not to exceed 10 pages.
- Proposers that are more than 50% owned by multiple venture capital operating companies (VCOC), hedge funds (HF), private equity firms (PEF) or any combination of these are eligible to submit proposals in response to DON topics advertised in this BAA. Information on Majority Ownership in Part and certification requirements at time of submission for these proposers are detailed in the section titled ADDITIONAL SUBMISSION CONSIDERATIONS.
- Phase I Technical Volume (Volume 2) and Supporting Documents (Volume 5) templates, specific to DON topics, are available at [https://www.navysbir.com/links\\_forms.htm](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.

### INTRODUCTION

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](http://www.navysbir.com). Additional information on DON's mission can be found on the DON website at [www.navy.mil](http://www.navy.mil).

**Digital Engineering.** DON desires the ability to design, integrate, and test naval products by using authoritative sources of system data, which enables the creation of virtual or digital models for learning and experimentation, to fully integrate and test actual systems or components of systems across disciplines to support lifecycle activities from concept through disposal. To achieve this, digital engineering innovations will be sought in topics with titles leading with DIGITAL ENGINEERING.

The Director of the DON SBIR/STTR Programs is Mr. Robert Smith. For questions regarding this BAA, use the information in Table 1 to determine who to contact for what types of questions.

**TABLE 1: POINTS OF CONTACT FOR QUESTIONS REGARDING THIS BAA**

Type of Question	When	Contact Information
------------------	------	---------------------

## VERSION 8

Program and administrative	Always	Program Managers list in Table 2 (below)
Topic-specific technical questions	BAA Pre-release	Technical Point of Contact (TPOC) listed in each topic. Refer to the Proposal Fundamentals section of the DoD SBIR/STTR Program BAA for details.
	BAA Open	DoD SBIR/STTR Topic Q&A platform ( <a href="https://www.dodsbirsttr.mil/submissions">https://www.dodsbirsttr.mil/submissions</a> ) Refer to the Proposal Fundamentals section of the DoD SBIR/STTR Program BAA for details.
Electronic submission to the DoD SBIR/STTR Innovation Portal (DSIP)	Always	DoD Help Desk via email at <a href="mailto:dodsbirsupport@reisystems.com">dodsbirsupport@reisystems.com</a>
Navy-specific BAA instructions and forms	Always	Navy-sbir-sttr.fct@navy.mil

**TABLE 2: DON SYSTEMS COMMANDS (SYSCOM) SBIR PROGRAM MANAGERS**

<u>Topic Numbers</u>	<u>Point of Contact</u>	<u>SYSCOM</u>	<u>Email</u>
N221-001 to N221-003	Mr. Jeffrey Kent	Marine Corps Systems Command (MCSC)	sbir.admin@usmc.mil
N221-004 to N221-024	Mr. Shawn Slade (Acting)	Naval Air Systems Command (NAVAIR)	navair.sbir@navy.mil
N221-025 to N221-066	Mr. Jason Schroepfer	Naval Sea Systems Command (NAVSEA)	NSSC_SBIR.fct@navy.mil
N221-067 to N221-076	Ms. Lore-Anne Ponirakis	Office of Naval Research (ONR)	onr-sbir-sttr.fct@navy.mil
N221-077 to N221-086	Mr. Michael Pyryt	Strategic Systems Programs (SSP)	ssp.sbir@ssp.navy.mil

### **PHASE I SUBMISSION INSTRUCTIONS**

The following section details what is required for a Phase I proposal submission to the DoD SBIR/STTR Programs.

(NOTE: Proposers are advised that support contract personnel will be used to carry out administrative functions and may have access to proposals, contract award documents, contract deliverables, and reports. All support contract personnel are bound by appropriate non-disclosure agreements.)

**DoD SBIR/STTR Innovation Portal (DSIP).** Proposers are required to submit proposals via the DoD SBIR/STTR Innovation Portal (DSIP); follow proposal submission instructions in the DoD SBIR/STTR Program BAA on the DSIP at <https://www.dodsbirsttr.mil/submissions>. Proposals submitted by any other

## VERSION 8

means will be disregarded. Proposers submitting through DSIP for the first time will be asked to register. It is recommended that firms register as soon as possible upon identification of a proposal opportunity to avoid delays in the proposal submission process. Proposals that are not successfully certified electronically in DSIP by the Corporate Official prior to BAA Close will NOT be considered submitted and will not be evaluated by DON. Please refer to the DoD SBIR/STTR Program BAA for further information.

**Proposal Volumes.** The following six volumes are required.

- **Proposal Cover Sheet (Volume 1).** As specified in DoD SBIR/STTR Program BAA.
- **Technical Proposal (Volume 2)**
  - Technical Proposal (Volume 2) must meet the following requirements or it will be REJECTED:
    - 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. Phase I Options are exercised upon selection for Phase II.
    - Phase I Base Period of Performance must be exactly six (6) months.
    - Phase I Option Period of Performance must be exactly six (6) months.
  - Additional information:
    - It is highly recommended that proposers use the Phase I proposal template, specific to DON topics, at [https://navysbir.com/links\\_forms.htm](https://navysbir.com/links_forms.htm) to meet Phase I Technical Volume (Volume 2) requirements.
    - A font size smaller than 10-point is allowable for headers, footers, imbedded tables, figures, images, or graphics that include text. However, proposers are cautioned that if the text is too small to be legible it will not be evaluated.
- **Cost Volume (Volume 3).**
  - Cost Volume (Volume 3) must meet the following requirements or it will be REJECTED:
    - The Phase I Base amount must not exceed \$140,000.
    - 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.
  - Additional information:
    - Provide sufficient detail for subcontractor, material, and travel costs. 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.
    - Inclusion of cost estimates for travel to the sponsoring SYSCOM’s facility for one day of meetings is recommended for all proposals.
    - The “Additional Cost Information” of Supporting Documents (Volume 5) may be used to provide supporting cost details for Volume 3. 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).

## VERSION 8

- **Company Commercialization Report (Volume 4).** DoD collects and uses Volume 4 and DSIP requires Volume 4 for proposal submission. Please refer to the Phase I Proposal section of the DoD SBIR/STTR Program BAA for details to ensure compliance with DSIP Volume 4 requirements.
- **Supporting Documents (Volume 5).** Volume 5 is for the submission of administrative material that DON may or will require to process a proposal, if selected, for contract award. All proposers must review and submit the following items, as applicable:
  - **Telecommunications Equipment Certification.** Required for all proposers. The DoD must comply with Section 889(a)(1)(B) of the FY2019 National Defense Authorization Act (NDAA) and is working to reduce or eliminate contracts, or extending or renewing a contract with an entity that uses any equipment, system, or service that uses covered telecommunications equipment or services as a substantial or essential component of any system, or as critical technology as part of any system. As such, all proposers must include as a part of their submission a written certification in response to the clauses (DFAR clauses 252.204-7016, 252.204-7018, and subpart 204.21). The written certification can be found in Attachment 1 of the DoD SBIR/STTR Program BAA. This certification must be signed by the authorized company representative and is to be uploaded as a separate PDF file in Volume 5. Failure to submit the required certification as a part of the proposal submission process will be cause for rejection of the proposal submission without evaluation. Please refer to the instructions provided in the Phase I Proposal section of the DoD SBIR/STTR Program BAA.
  - **Disclosure of Offeror's Ownership or Control by a Foreign Government.** All proposers must review to determine applicability. In accordance with DFARS provision 252.209-7002, a proposer is required to disclose any interest a foreign government has in the proposer when that interest constitutes control by foreign government. All proposers must review the Foreign Ownership or Control Disclosure information to determine applicability. If applicable, an authorized firm representative must complete the Disclosure of Offeror's Ownership or Control by a Foreign Government (found in Attachment 2 of the DoD SBIR/STTR Program BAA) and upload as a separate PDF file in Volume 5. Please refer to instructions provided in the Phase I Proposal section of the DoD SBIR/STTR Program BAA.
  - **Majority Ownership in Part.** Proposers which are more than 50% owned by multiple venture capital operating companies (VCOC), hedge funds (HF), private equity firms (PEF), or any combination of these as set forth in 13 C.F.R. § 121.702, are eligible to submit proposals in response to DON topics advertised within this BAA. Complete certification as detailed under ADDITIONAL SUBMISSION CONSIDERATIONS.
- Additional information:
  - Proposers may include the following administrative materials in Supporting Documents (Volume 5); a template is available at [https://navysbir.com/links\\_forms.htm](https://navysbir.com/links_forms.htm) to provide guidance on optional material the proposer may want to include in Volume 5:
    - Additional Cost Information to support the Cost Volume (Volume 3)
    - SBIR/STTR Funding Agreement Certification
    - Data Rights Assertion
    - 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

## VERSION 8

- Do not include documents or information to substantiate the Technical Volume (Volume 2) (e.g., resumes, test data, technical reports, or publications). Such documents or information will not be considered.
- A font size smaller than 10-point is allowable for documents in Volume 5; however, proposers are cautioned that the text may be unreadable.
- **Fraud, Waste and Abuse Training Certification (Volume 6).** DoD requires Volume 6 for submission. Please refer to the Phase I Proposal section of the DoD SBIR/STTR Program BAA for details.

### PHASE I EVALUATION AND SELECTION

The following section details how the DON SBIR/STTR Programs will evaluate Phase I proposals.

Proposals meeting DoD SBIR/STTR submission requirements will be forwarded to the DON SBIR/STTR Programs for evaluation. Prior to evaluation, all proposals will undergo a compliance review to verify compliance with DoD and DON SBIR/STTR submission requirements. Proposals not meeting submission requirements will be REJECTED and not evaluated.

- **Proposal Cover Sheet (Volume 1).** Not evaluated. The Cover Sheet (Volume 1) will undergo a compliance review (prior to evaluation) to verify the proposer has met eligibility requirements.
- **Technical Volume (Volume 2).** The DON will evaluate and select Phase I proposals using the evaluation criteria specified in the Phase I Proposal Evaluation Criteria section of the DoD SBIR/STTR Program BAA, with technical merit being most important, followed by qualifications of key personnel and commercialization potential of equal importance. “Best value” is defined as approaches containing innovative technology solutions to the Navy’s technical challenges for meeting its mission needs as reflected in the SBIR/STTR topics. This is not a FAR Part 15 evaluation and proposals will not be compared to one another. Cost is not an evaluation criteria and will not be considered during the evaluation process. Due to limited funding, the DON reserves the right to limit the number of awards under any topic.

The Technical Volume (Volume 2) will undergo a compliance review (prior to evaluation) to verify the proposer has met the following requirements or it will be REJECTED:

- 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, except as permitted in the instructions above.
- 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.
- Phase I Base Period of Performance must be exactly six (6) months.
- Phase I Option Period of Performance must be exactly six (6) months.
- **Cost Volume (Volume 3).** Not evaluated. The Cost Volume (Volume 3) will undergo a compliance review (prior to the proposal evaluation) to verify the proposer has complied with not

## VERSION 8

to exceed values for the Base (\$140,000) and Option (\$100,000). Proposals exceeding either the Base or Option not to exceed values will be REJECTED without further consideration.

- **Company Commercialization Report (Volume 4).** Not evaluated.
- **Supporting Documents (Volume 5).** Not evaluated. Supporting Documents (Volume 5) will undergo a compliance review to ensure the proposer has included items in accordance with the PHASE I SUBMISSION INSTRUCTIONS section above.
- **Fraud, Waste, and Abuse Training Certificate (Volume 6).** Not evaluated.

### **ADDITIONAL SUBMISSION CONSIDERATIONS**

This section details additional items for proposers to consider during proposal preparation and submission process.

**Discretionary Technical and Business Assistance (TABA).** The SBIR and STTR Policy Directive section 9(b) allows the DON to provide TABA (formerly referred to as DTA) to its awardees. The purpose of TABA 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 by the proposer 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. A TABA Report, detailing the results and benefits of the service received, will be required annually by October 30.

Request for TABA funding will be reviewed by the DON SBIR/STTR Program Office.

If the TABA request does not include the following items the TABA request will be denied.

- 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 proposer
- Propose a TABA provider that is the SBIR proposer
- Propose a TABA provider that is an affiliate of the SBIR proposer
- Propose a TABA provider that is an investor of the SBIR proposer
- 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)

## VERSION 8

TABA requests must be included in the proposal as follows:

- Phase I:
  - Online DoD Cost Volume (Volume 3) – the value of the TABA request.
  - Supporting Documents Volume (Volume 5) – a detailed request for TABA (as specified above) specifically identified as “Discretionary Technical and Business Assistance” in the section titled Additional Cost Information.
- Phase II:
  - DON Phase II Cost Volume (provided by the DON SYSCOM) - the value of the TABA request.
  - Supporting Documents (Volume 5) – a detailed request for TABA (as specified above) specifically identified as “Discretionary Technical and Business Assistance” in the section titled Additional Cost Information.

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

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 Phase II 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.

**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 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 (defined by National Security Decision Directive 189). A firm whose proposed work will include fundamental research and requests to eliminate the requirement for prior approval of public disclosure of information must complete the DON Fundamental Research Disclosure and upload as a separate PDF file to the Supporting Documents (Volume 5) in DSIP as part of their proposal submission. The DON Fundamental Research Disclosure is available on [https://navysbir.com/links\\_forms.htm](https://navysbir.com/links_forms.htm) and includes instructions on how to complete and upload the completed Disclosure. Simply identifying fundamental research in the Disclosure does **NOT** constitute acceptance of the exclusion. All exclusions will be reviewed and, if approved by the government Contracting Officer, noted in the contract.

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

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

## VERSION 8

be accepted and evaluated:

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

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

**Notice of NIST SP 800-171 Assessment Database Requirement.** The purpose of the National Institute of Standards and Technology (NIST) Special Publication (SP) 800-171 is to protect Controlled Unclassified Information (CUI) in Nonfederal Systems and Organizations. As prescribed by DFARS 252.204-7019, in order to be considered for award, a firm is required to implement NIST SP 800-171 and shall have a current assessment uploaded to the Supplier Performance Risk System (SPRS) which provides storage and retrieval capabilities for this assessment. The platform Procurement Integrated Enterprise Environment (PIEE) will be used for secure login and verification to access SPRS. For brief instructions on NIST SP 800-171 assessment, SPRS, and PIEE please visit <https://www.sprs.csd.disa.mil/nistsp.htm>. For in-depth tutorials on these items please visit <https://www.sprs.csd.disa.mil/webtrain.htm>.

**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: <https://www.onr.navy.mil/work-with-us/how-to-apply/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 technical merit of 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



## VERSION 8

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).

### **SELECTION, AWARD, AND POST-AWARD INFORMATION**

**Notifications.** Email notifications for proposal receipt (approximately one week after the Phase I BAA Close) and selection are sent based on the information received on the proposal Cover Sheet (Volume 1). Consequently, the e-mail address on the proposal Cover Sheet must be correct.

**Debriefs.** 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.** 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 2. If the protest is to be filed with the GAO, please refer to instructions provided in the Proposal Fundamentals section of the DoD SBIR/STTR Program BAA.

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

**Awards.** Due to limited funding, the DON reserves the right to limit the number of awards under any topic. Any notification received from the DON that indicates the proposal has been selected does not ultimately guarantee an award will be made. This notification indicates that the proposal has been selected in accordance with the evaluation criteria and has been sent to the Contracting Officer to conduct cost analysis, confirm eligibility of proposer, and to take other relevant steps necessary prior to making an award.

**Contract Types.** 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 the section of the DoD SBIR/STTR Program BAA titled Proposal Fundamentals, 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

## VERSION 8

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.

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

**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.

### **PHASE II GUIDELINES**

**Evaluation and Selection.** All Phase I awardees may submit an **Initial** Phase II proposal for evaluation and selection. The evaluation criteria for Phase II is the same as Phase I. 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 BAAs prior to FY13 will be conducted in accordance with the procedures specified in those BAAs (for all DON topics, this means by invitation only).

**Awards.** 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. Consequently, DON will assign SBIR/STTR Data Rights to any noncommercial technical data and noncommercial computer software

## **VERSION 8**

delivered in Phase III that were developed under SBIR/STTR Phase I/II effort(s). Government prime contractors and 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.

# VERSION 8

## Navy SBIR 22.1 Phase I Topic Index

N221-001	DIGITAL ENGINEERING - Civilian Behavior Conceptual Models for Wargaming
N221-002	Ultra Lightweight Tactical Vehicle Power Generation
N221-003	Remote Expeditionary Autonomous Pioneer System
N221-004	DIGITAL ENGINEERING - Embedded Aircraft Design Geometry in Multidisciplinary Design Optimization Frameworks
N221-005	DIGITAL ENGINEERING - Photonics Integration for Modular Open Systems Approach Avionics Plug-in Modules
N221-006	Room-Temperature Filler for Honeycomb Repairs
N221-007	Data-Driven Physics-Based Modeling Tools to Determine Effective Mechanical Properties of As-Built Composite Structures
N221-008	Innovative Approaches to Reducing the Complexity and Increasing Sustainability of Linkless Ammunition Loading System III
N221-009	Automated System to Assist in Gauge Block Calibration
N221-010	Magnetometer Classification of Underwater Objects
N221-011	Low-Cost, Large, Multidimensional, High-Sensor-Density, Collapsible Arrays
N221-012	Advanced Jam-Resistant Radar Waveforms
N221-013	Development of High-Viscosity Pre-Penetrant Etching Materials
N221-014	Synthetic Aperture Radar High Resolution Imaging when Performing Random Nonrepeating Radar Orbits
N221-015	Electromagnetic Interactions Between Cables, Antennas, and Their Environments
N221-016	Autonomous Onboard Processing Hostile Fire Sensor System
N221-017	Manned-Unmanned Teaming Survival in an Adaptive World
N221-018	Smart Avionics Systems Environment for Automatic Test Systems
N221-019	Long-Range Passive Surveillance in Anti-Access/Area-Denial Environments
N221-020	Heat Tolerant Decoy Towline for Towed Decoy
N221-021	Modeling and Process Planning Tool for Hybrid Metal Additive/Subtractive Manufacturing to Control Residual Stress and Reduce Distortion

## VERSION 8

N221-022	Compact Thermal Energy Storage
N221-023	Miniaturized Sonobuoy High-Data-Rate Tether
N221-024	Automated Air Traffic Control Communication Technology Enhancement
N221-025	DIGITAL ENGINEERING - Advanced Technologies for Automated Replay and Reconstruction of Theater Undersea Warfare Mission Data
N221-026	DIGITAL ENGINEERING - Automated Network Cluster Generation
N221-027	DIGITAL ENGINEERING - Undersea Warfare Tactical Advantage Support Kit
N221-028	DIGITAL ENGINEERING - Unmanned Harbor Piloting
N221-029	DIGITAL ENGINEERING - Artificial Intelligence /Machine Learning Applications to STANDARD Missile Maintenance Data
N221-030 Toolset	DIGITAL ENGINEERING - Design for Additive Manufacturing (DfAM) Risk
N221-031	DIGITAL ENGINEERING - Distributed Mission Effectiveness and Readiness Management System
N221-032	DIGITAL ENGINEERING - 3D Operator Decision Aides for Ship Control Systems
N221-033	DIGITAL ENGINEERING - Perception System for Situational Awareness and Contact Detection for Unmanned Underwater Vessels
N221-034	DIGITAL ENGINEERING - Combatant Craft Autonomy-Enabling Sensors, Perception and Command & Control
N221-035	DIGITAL ENGINEERING - Multi-Beam Antenna Scheduling Optimization
N221-036	DIGITAL ENGINEERING - Exploitation of Ephemeral Features in Sonar Classification Algorithms
N221-037	Compact Electron Beam Focusing System for Millimeter Wave Sources
N221-038	Navy Threshold Velocity Detector Redesign
N221-039	Flexible Unmanned Vehicle Stowage System
N221-040	Shipboard Advanced Metal Manufacturing Machine
N221-041	Compact High Power Mid-Wave Infrared Laser System
N221-042	Advanced Piezoelectric Materials in Maritime Surveillance Systems

## VERSION 8

N221-043	Enhanced Performance Radome Materials for High Speed Missiles
N221-044	Compact, High Performance Mid-Wave Infrared Sensor for Intermittent Deployment
N221-045	Fiber Optic Cable for Radio Frequency Over Fiber Links
N221-046	Velocity-Over-Ground Sensor for Inertial Navigation System Error Reduction
N221-047	Over The Shore Messenger Line Delivery System
N221-048	Well Deck Securing System for Landing Craft Utility
N221-049	Radar Absorbing Material Maintainability Improvements
N221-050	Advanced Cyber Threat Hunting Toolkit for Deployed Tactical Platforms
N221-051	Enhanced Performance for Fin and Control Surface Materials for High Speed Missiles
N221-052	Low Hazard Heat Pump for Distributed Cooling
N221-053	Multi-Aperture Vector Sensor Vertical Array Processing Enhancements to Reduce Operator Workload
N221-054	Modernized Navy Fan-Coil Assembly
N221-055	Improved Towed Array Acoustic Hose
N221-056	Unmanned, Autonomous Avoidance of Active Acoustics Harassment of Marine Mammals
N221-057	Alternative Power for Anti-Submarine Warfare Targets
N221-058	Electronic Warfare Human Machine Interface Training
N221-059	Directional Acoustic Communications Transmitters
N221-060	Chip Scale Oceanographic Sensor
N221-061	Kill Assessment and Closely Spaced Object Resolution with Elevated Electro-Optic/Infrared (EO/IR)
N221-062	Universal Environmental Controls for AM Machines
N221-063	Nonlinear Mitigated Gain Fiber Development for kW-class Fiber Lasers
N221-064	Medium Voltage Direct Current Disconnect Switches
N221-065	Low Cost, Small Form Factor Scalable Receive Array

## VERSION 8

N221-066	New Water-Blocking Chemicals/Materials for Zero Longitudinal Seawater Flow through Navy Outboard Cables
N221-067	<del>DIGITAL ENGINEERING</del> Improved Reliability of Composites Pi-Joints for use in Primary Aircraft Structures
N221-068	DIGITAL ENGINEERING - Requirements Management Tool for Design of Effective Human Machine Systems with Evolving Technologies
N221-069	DIGITAL ENGINEERING - Digital Twins to Enable Training (DTET)
N221-070	Acoustic Vector Sensors that Achieve Affordable Array Directivity
N221-071	Forensic Memory for Self-Cued, Data-Thinning Receivers
N221-072	Low-Cost Deployable Structures for Sonobuoy Arrays
N221-073	Radio Frequency Spectrum Patterns of Life
N221-074	Turbine Engine Efficiency improvements by Additive Manufacturing
N221-075	Enhanced Lethality Warhead
N221-076	Lightweight, Compact, and Cost-effective Gaseous Hydrogen Storage System
N221-077	DIGITAL ENGINEERING - Semantically-Driven Data Integration Software Solutions
N221-078	Split Ratio Fine-Tuning Feature for Integrated Optical Circuits in Interferometric Fiber-Optic Gyroscopes
N221-079	Low-Loss, Low-Aberration, Numerical Aperture-Matched Microlens Arrays to Improve Coupling Efficiency onto Photonic Imaging Devices.
N221-080	Development of a Time-Triggered Ethernet Intellectual Property Block
N221-081	Development of an Aerothermal Modeling and Simulation Code for Hypersonic Applications
N221-082	Integrated Complementary Metal Oxide Semiconductor Nuclear Event Detector for System on a Chip Applications
N221-083	Variable Conductance Thermal Management Technology
<del>N221-084</del>	[Navy has removed topic N221-084 from the 22.1 SBIR BAA]
N221-085	Integration Strategy for Complementary Metal Oxide Semiconductor-based Terahertz Spectroscopy Systems
<del>N221-086</del>	[Navy has removed topic N221-086 from the 22.1 SBIR BAA]

## VERSION 8

N221-001      TITLE: DIGITAL ENGINEERING - Civilian Behavior Conceptual Models for Wargaming

OUSD (R&E) MODERNIZATION PRIORITY: Networked C3

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Develop Civilian Pattern of Life models, sufficient to withstand review board scrutiny to support model verification, validation, and accreditation, as required. Focus on developing and implementing the models referenced herein, not on the underlying mechanics of the Program Manager Wargaming Capability (PM WGC) materiel solution simulation framework.

DESCRIPTION: This SBIR topic addresses two parametrics of interest for future inclusion in the Marine Corps Wargaming and Analysis Center (MCWAC), both related to modeling civilian populations. In the table below, the two major parametrics considered are “Civilian Pattern of Life” and “Civilian Populations.” The specific conceptual model requirements are listed for each parametric.

ID	Parametric	Parametric Description	Conceptual Model Requirements
Info1	Civilian pattern of life (traffic patterns on the air, land, and sea)	Basic needs (food, water, shelter); basic economic behaviors (work locations, work activities); basic religious behaviors (worship times, locations, behaviors); basic reactions to military activities (bombs, blue forces presence, red forces presence); etc.	Identify geographic locations of homes, places of business, schools, religious activities, and social activities.
Info2			Represent opening hours for places of business, schools, religious activities, and social activities.
Info3			Represent statistical demographics based on age, gender, and social role.
Info4			Represent aggregate daily civilian location based on geographic locations, opening hours, and statistical demographics.
Info5			Identify recurring, large-scale activities impacting civilian activities.
Info6			Simulate changes to daily civilian location based on recurring, large-scale activities.
Info7			Identify anomalous circumstances impacting daily civilian activities.
Info8			Simulate changes to daily civilian location based on anomalous circumstances.



## VERSION 8

Info9			Identify aggregate daily land vehicle traffic.
Info10			Identify aggregate daily foot traffic.
Info13			Identify aggregate daily civilian resource requirements
Info16			Simulate daily civilian movements between locations based on LOCE CoD requirements.
Info17			Identify minimum daily civilian resource requirements.
Info18			Simulate individual civilian daily traffic based on geographic locations, opening hours, statistical demographics, and all forms of daily traffic.
Info19			Simulate changes to individual daily traffic based on recurring, large-scale activities.
Info20			Simulate changes to individual daily traffic based on anomalous circumstances impacting daily civilian activities.
Info22	Civil populations have atmospheric (culture, society, economic, technology, and density); personal intent and perceptions; and human dynamics for both domestic and foreign groups. The collection affects the political and military environments based upon the knowledge and perceptions of the collection.	This is just the representation of civilian representations. There is a parallel effort to look at the data and validity of the data.	Identify political parties, religions (sects), families, social / cultural organizations, professional organizations, and prominent figures with which individuals may have affiliations.
Info23			Identify sentiments, positions / beliefs, and goals associated with all affiliations.
Info24			Represent civilian affiliations in the aggregate based on age, gender, and social role.
Info25			Simulate changes in sentiments, positions / beliefs, and goals associated with all affiliations based

## VERSION 8

			on changes in the physical environment.
Info26			Simulate changes in sentiments, positions / beliefs, and goals associated with all affiliations based on changes in the social, political, economic, and cultural environment.

Some examples under the above headings include, but are not limited to:

- Model civil infrastructure networks for Food, Water, Sewage, Power, Fuel, Communications.
- Model key civil infrastructure facilities to include religious centers, medical treatment, civil supply, law enforcement.
- Model displacement of civilians due to military activity (or disasters) that causes them to require shelter, medical attention, and food.
- Model the relationship between various civil factions including level of violence.
- Model incidents of violence (fully automated). Military action (or lack of) can suppress these incidents.
- Model the positive or negative "influence" of one faction versus another, a key metric for Stability and Support Operations (SASO).

Full satisfaction of each conceptual model requirement is the end goal; however, partial solutions will be considered. This topic specifically focuses on developing the mathematical, algorithmic, and data aspects of the conceptual models. The mechanism by which these conceptual models would be implemented within the MCWAC is not the focus. Documentation of the conceptual models with Cameo/SysML is desirable, but not necessarily a strict requirement, if another representation is more suitable [Ref 2].

**PHASE I:** Develop concepts for an improved representation of civilian populations in wargaming Modeling and Simulation (M&S) that meets the requirements described above. Demonstrate the feasibility of the concepts in meeting Marine Corps needs and establish that the concepts can be developed into a useful product for the Marine Corps. Feasibility will be established by evaluation of the plan of attack for the development effort including data availability. Provide a Phase II development plan with performance goals and key technical milestones, and that will address technical risk reduction.

**PHASE II:** Develop prototype conceptual models to be evaluated to determine its capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for civilian populations M&S. System performance will be demonstrated through prototype evaluation over the required range of parameters. Evaluation results will be used 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 civilian population conceptual model implementations for evaluation to determine their effectiveness in an operationally relevant environment within the MCWAC. Support the Marine Corps for M&S Verification, Validation, and Accreditation (VV&A) to certify and qualify the system for Marine Corps use.

The conceptual models described herein are not only a high priority within the Marine Corps [Ref 1], but are equally applicable across the Services, to support not only wargaming, but also analysis, training, and experimentation. Successfully developed conceptual models would likely be of great interest across these

## VERSION 8

communities. Outside DoD, marketing firms would be a natural customer, looking to understand patterns of civilian behavior from which to develop market segmentation strategies and ultimately advertisement campaigns.

### REFERENCES:

1. "Commandant's Planning Guidance, 38th Commandant of the Marine Corps, 2019."  
[https://www.marines.mil/Portals/1/Publications/Commandant's%20Planning%20Guidance\\_2019.pdf?ver=2019-07-17-090732-937](https://www.marines.mil/Portals/1/Publications/Commandant's%20Planning%20Guidance_2019.pdf?ver=2019-07-17-090732-937).
2. "Distributed Simulation Engineering and Execution Process." IEEE 1730-2010, January 2011.  
<https://www.sisostds.org/StandardsActivities/SupportGroups/DSEPDMAOPSG-DistributedSimulationEngineerin.aspx>.

KEYWORDS: Wargaming; Modeling and Simulation; M&S; Civilian Pattern of Life; Conceptual Model; Marine Corps Wargaming and Analysis Center; MCWAC; Program Manager Wargaming Capability; PM WGC; Information modeling

## VERSION 8

N221-002 TITLE: Ultra Lightweight Tactical Vehicle Power Generation

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a compact, lightweight, and engine driven power generation system for energy export power with high specific power (kilowatts per kilogram) that fits within the confines of the chassis of recreational off-highway vehicles (ROVs) to meet expected power and energy demands and allow for future mission growth.

DESCRIPTION: Currently available vehicles capable of being internally transported in rotary wing aircraft have insufficient export power capabilities to meet power and energy demands of current Counter-Unmanned Aerial Systems (C-UASs) and allow for future mission growth. The current Light Marine Air Defense Integrated System (LMADIS) uses a 5 kilowatts (kW) diesel generator weighing 300 lbs. that results in the vehicle weighing 15 lbs. over the maximum gross vehicle weight (GVW) of the current Ultra Lightweight Tactical Vehicle (ULTV). Future mission growth to add additional communications equipment to LMADIS is expected to increase the power demands to 10 kW. Currently available diesel generators that meet the higher power requirements weigh close to 500 lbs. and would result in the vehicle weighing 100 to 150 lbs. over maximum Gross Vehicle Weight (GVW). Compact and lightweight power generation systems are needed to power C-UAS and C2 systems and keep the vehicle safely within its allowable GVW. System requirements are:

- Integrated system using the existing Polaris MRZR-ALPHA 118hp 1.5L Ford diesel engine
- Export power output of 10 kW at idle Threshold (T); 15 kW at idle Objective (O) at 28 volts direct current (VDC)
- Reduced physical size of export power system (same approximate size as an alternator, 8 inches wide x 10 inches long x 8 inches high)
- Physical weight of export power system less than 125 lbs.
- Compatible with typical 28VDC tactical electrical systems and 14VDC vehicle electrical systems while conforming to the necessary requirements within MIL-STD-1275E, MIL-STD-1332B, and MIL-STD-705D
- Electrical component and connections with an ingress protection rating of Ingress Protection (IP67) or higher in accordance with (IAW) American National Standards Institute (ANSI) / International Electrotechnical Commission (IEC) 60529-2004
- Modular design that can be inspected, serviced, and repaired in the field
- Full power output across the range of engine speeds, ~750-4,500 Revolutions Per Minute (RPM)
- Operate at temperatures between 0°F to 125°F (T); -25°F to 125°F (O)

PHASE I: Develop concept(s) for a generator technology and its supporting control equipment that can meet the requirements described above. Demonstrate the feasibility of the concept(s) in meeting the Marine Corps needs and establish that the concepts can be developed into a useful product for the Marine Corps. Feasibility will be established by material testing and/or analytical modeling, as appropriate. Provide a Phase II development plan with performance goals, key technical milestones, and address technical risk reduction.

PHASE II: Develop a full-scale prototype for evaluation. The prototype shall be evaluated through bench or lab testing to determine its capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirement for the integrated power generation system. System performance shall be demonstrated through prototype evaluation and modeling or analytical methods over the required range of parameters including numerous deployment cycles. Evaluate the results and refine the design as necessary. Conduct on-vehicle testing in a relevant environment. Evaluate and compare the

## VERSION 8

results to Marine Corps requirements. Prepare a Phase III development plan to transition the technology for Marine Corps and commercial use.

PHASE III DUAL USE APPLICATIONS: Provide support to the Marine Corps in transitioning the technology for Marine Corps use. Refine a power generation system for further evaluation and determine its effectiveness in an operationally relevant environment. Support the Marine Corps test and evaluation program to qualify the system for the Marine Corps use.

Commercial applications include law enforcement vehicles, search and rescue vehicles, tractor trailers, and general automotive platforms to provide integrated power capability reducing both weight and space claim supporting a more demanding future mobile power environment.

### REFERENCES:

1. "MIL-STD-1275E Characteristics of 28 Volt DC Input Power to Utilization Equipment in Military Vehicles." U.S. Army Tank automotive and Armaments Command, March 22, 2013. [https://quicksearch.dla.mil/qsDocDetails.aspx?ident\\_number=36186](https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=36186).
2. "MIL-STD-1332B Tactical, Prime, Precise, and Utility Terminologies For Classification of the DoD Mobile Electric Power Engine Generator Set Family." Naval Facilities Engineering Command, Naval Construction Battalion Center, March 13, 1973. [https://quicksearch.dla.mil/qsDocDetails.aspx?ident\\_number=36687](https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=36687).
3. "MIL-STD-705D Mobile Electric Power Systems." Communications Electronics Research Development Engineering Center (CERDEC) Product Realization Directorate (PRD), November 22, 2016. [https://quicksearch.dla.mil/qsDocDetails.aspx?ident\\_number=35902](https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=35902).
4. "ANSI/IEC 60529-2004 Degrees of Protection Provided by Enclosures (IP Code)." <https://www.nema.org/Standards/ComplimentaryDocuments/ANSI-IEC-60529.pdf>.

KEYWORDS: Tactical vehicle; power generation; weight reduction; size reduction; ultra lightweight tactical vehicle; ULTV; Light Marine Air Defense Integrated System; LMADIS; Exportable power; Power

## VERSION 8

N221-003 TITLE: Remote Expeditionary Autonomous Pioneer System

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy; General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop an expeditionary system that integrates a multiplicity of capabilities currently provided by several separate and distinct systems that provide material handling, construction, path/trail clearance, explosive hazard defeat capabilities, and refueling into a single system; and would utilize separate “attachments” or end-effectors to perform the various missions.

DESCRIPTION: The intent of this SBIR topic is to develop a system that integrates material handling, construction, path/trail clearance, and explosive hazard defeat capabilities into a single system. The system may be configured as a “base” and incorporate various attachments for each specific application. It is desired that the system require a minimum amount of operational input from personnel, including the changing of attachments. The system must be transportable by Marine Corps ground and air assets. Proposals should specifically describe the technology that will be applied to solve the problem, how it will be developed, what estimated benefits will be, and how it might be transitioned to the Marine Corps.

### Definitions:

- Systems must meet Threshold requirements = (T)
  - It is highly desirable for the system meets Objective requirements = (O)
1. Ability to meet the requirements of the Marine Corps in all of its operating environments (MIL-STD-810) (T=O)
  2. Capable of repair in the field with plug-and-play line replaceable units or parts produced by expeditionary advanced manufacturing (additive manufactured 3D printed/subtractive manufactured Computer Numerical Control (CNC) milling or lathing parts) (T=O)
  3. Able to be deployed and operational by 1 person within 30 minutes (T), less than 5 minutes (O), starting from its transport configuration
  4. Retrievable and ready for transport within 30 minutes (T), less than 5 minutes (O)
  5. Operated with little or no human intervention. Single-person wireless remote operation (T); Fully Autonomous operation (O)
  6. Base system weight: 5,000 lbs (T), 4,000 lbs (O)
  7. Transportability:
    - a. Aircraft: CH-53 (T), MV-22 (O)
    - b. Ground: MTRV (T), JLTV Trailer (O)
  8. Propulsion: diesel, electric, or hybrid
  9. Run Time: 4 hours (T), 8 hours (O)
  10. Operable in rivers or streams with a depth of 1 m (T=O)
  11. Capable of operation in fresh and brackish water (T=O)
  12. Mission Attachments
    - a. The base system will connect to attachments with limited human intervention (T), or no human intervention (O). A universal skid steer adapter is an example of a tool that may facilitate this function.
    - b. The time to connect/disconnect attachments will be 30 min (T), or 5 min (O).
  13. Examples of desired Mission Capabilities that may require separate, distinct attachments to perform each task identified below:
    - a. The base system may use commercial off-the-shelf (COTS) attachments. As an example, the Airfield Damage Repair Kit with the following attachments:

## VERSION 8

- i. Compactor, Vibratory (NSN 3805-01-553-7850, PN 231-8601, CAGE 11083)
    - ii. Hydraulic Hammer (PN 435-5318 CAGE 11083)
    - iii. Angle Broom Attachment (PN 448-5670 CAGE 11083)
    - iv. Fork Attachment (NSN 3930-01-561-7981, PN 353-1697, CAGE 11083)
    - v. Bucket Attachment (PN 426-6947 CAGE 11083)
  - b. Material Handling
    - i. Payload: 11,200 lbs (T=O)
    - ii. Lift Capacity: 5,000 lbs (T), 11,200 lbs (O)
    - iii. Lift Height: 60" (T), 72" (O)
    - iv. Adjustable forks and mast
  - c. Explosive Hazard Defeat
    - i. Flail
    - ii. Mine Roller
    - iii. Breaching
    - iv. Marking
  - d. Counter Mobility
    - i. Create man-made obstacles
    - ii. Emplacement of lethal area denial capabilities
  - e. Fueling
    - i. Remote/Autonomous refueling of ground vehicles; e.g, JLTV, MTRV, LVSR (T)
    - ii. Remote/Autonomous refueling of aviation assets (O)
  - f. Fire Suppression
  - g. Auxiliary Power Generation: 1,500W (T), 5,000W (O)
- 14. The system software will employ an open architecture; e.g., Robotic and Operating Systems – Modular (ROS-M) or Robotic Operating System (ROS) (T=O)
- 15. Cost, Base System: cost < \$50,000 (O)

PHASE I: Develop concepts for a REAPr that meets the requirements described above. Demonstrate the feasibility of the concepts in meeting the Marine Corps requirements. Establish that the concepts can be developed into a useful product for the Marine Corps. Feasibility will be established 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 REAPr. Demonstrate system performance through prototype evaluation and modeling or analytical methods over the required range of parameters including numerous deployment cycles. Evaluation results will be used to refine the prototype into an initial design that will meet Marine Corps and REAPr requirements; and for evaluation to determine its effectiveness in an operationally relevant environment approved by the Government. 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. Support the Marine Corps for test and validation to certify and qualify the system for Marine Corps use.

Commercial applications may include, but not be limited to: material handling in finished and austere environments; forestry and logging; public safety; demining and clearance; construction and earth

## VERSION 8

movement; aviation (material handling and fueling). Additionally, the system lends itself to operations in remote locations that may not be accessible by traditional construction equipment.

### REFERENCES:

1. ROS-M ROS Military Public Website. US Army CCDC Ground Vehicle Systems Center. [www.rosmilitary.org](http://www.rosmilitary.org).
2. “Remote Controlled Tracked Carriers, PT-300 D:MINE.” FAE Group S.p.A., 2020. [https://www.fae-group.com/en\\_US/products/demining/demining-tracked-carriers/remote-controlled-tracked-carriers/pt-300-d-mine](https://www.fae-group.com/en_US/products/demining/demining-tracked-carriers/remote-controlled-tracked-carriers/pt-300-d-mine).
3. Built Robotics. Built Robotics Inc. <https://www.builtrobotics.com/>.

KEYWORDS: autonomous; robot; material handling; expeditionary; maneuver; construction; explosive hazard; mine; mobility; Remote Expeditionary Autonomous Pioneer System; REAPr



## VERSION 8

N221-004 TITLE: DIGITAL ENGINEERING - Embedded Aircraft Design Geometry in Multidisciplinary Design Optimization Frameworks

OUSD (R&E) MODERNIZATION PRIORITY: Hypersonics

TECHNOLOGY AREA(S): Air Platforms

OBJECTIVE: Develop and demonstrate a conceptual design geometry tool capable of embedding in fixed- and rotary-wing multidisciplinary optimization frameworks to enable improved estimates of cost and technical feasibility during requirements development and concept refinement of new manned aircraft, unmanned aircraft systems, and weapons.

DESCRIPTION: Early in the acquisition lifecycle of a new air vehicle—Pre-milestone A—the Department of Defense (DoD) conducts aircraft conceptual design studies to determine the technical feasibility of potential requirements sets. The DoD uses these conceptual designs to estimate the development, production, and operating cost of the aircraft program. They also use the designs as inputs to virtual and constructive modeling and simulation (M & S) tools. The DoD uses M & S to quantify the military effectiveness of the aircraft design. Finally, the DoD uses this combination of cost vs. effectiveness data as the basis for decisions setting the requirements for the new aircraft development program.

This process can be used for all sizes and types of air vehicles, from manned tactical aircraft like strike fighters, to rotary-wing vehicles like helicopters and tilt-rotors, to small unmanned aircraft and weapons. This forms the start of the Model-Based System Engineering (MBSE) process. At Naval Air Warfare Center Aircraft Division (NAWCAD), this process is conducted by the Mission Engineering and Analysis Department (MEAD). MEAD engineers use multidisciplinary analysis and optimization (MDAO) software frameworks to find the best possible design for each potential requirement set under evaluation.

This current process is significantly hampered by the lack of a 3D aircraft geometry modeling tool that can be embedded within MDAO frameworks. MEAD engineers need an ability to visualize the geometry they are entering into the MDAO framework in order to support program offices as they look at new and innovative air vehicles, from hypersonic weapons to manned rotary-wing platforms to Unmanned Aerial Vehicles (UAVs) designed specifically for manned-unmanned-teaming. They also need the ability to generate 3D models of the aircraft results produced by the MDAO framework. Currently, commercial CAD packages are not flexible enough to handle the large variations in geometry produced during an MDAO run. Some open source parametric geometry tools are flexible enough, but do not allow the Application Programming Interface (API) to be used while the Graphical User Interface (GUI) is open.

This geometry modeling tool must allow parametric modeling of a wide variety of classes of aircraft and nonconventional arrangements. It should include an aircraft conceptual design specific geometry parametrization, and provide a fully documented, fully unit tested API that allows communication with MDAO software while the geometry tool GUI is open. It must include a GUI that enables MEAD and program office engineers to visualize geometry as they input it to MDAO software, and as the MDAO software returns results. The geometry tool should provide the flexibility to easily generate new aircraft configurations, with the capability for an engineer to start from a blank file and create all major aircraft components in less than one hour. All features available in the API should be available in the GUI, and all features available in the GUI should be available in the API. It must be capable of generating multiple geometry models for analysis from a single authoritative model, including the ability to generate geometry input data for Vortex Lattice aerodynamic analysis. It should be capable of modeling both fixed-and rotary-wing vehicle geometries. It must be capable of exporting 3D watertight trimmed geometry models in both IGES and STEP formats. It must be capable of modeling internal component

## VERSION 8

layouts and outer mold line geometry shapes. It should be capable of providing geometry measurements including surface areas, volumes, cross sectional areas, and projected areas. It should be capable of running on both Windows and Linux operating systems.

PHASE I: Demonstrate the feasibility of an aircraft geometry modeling tool that can be embedded in an MDAO framework. This demonstration will test integration with both the Aircraft Design, Analysis, Performance, and Tradespace (ADAPT) framework produced by the DoD High Performance Computing Modernization Program (HPCMP), and with An Integrated Design Environment for NASA Design and Analysis of Rotorcraft (AIDEN/NDARC). The government will provide access to both ADAPT and AIDEN for development and demonstration. The demonstration of at least one feature in the API working while the GUI is open, providing two-way communication between the geometry tool and ADAPT is a critical goal of Phase I. The demonstration of two-way communication between the geometry tool and both AIDEN is also a critical goal of Phase I. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype fully featured geometry tool, with all capabilities available within the API while the GUI is running. Direct integration with both ADAPT and AIDEN frameworks should be completed. Several classes of military aircraft should be demonstrated (fighters, helicopters, hypersonic weapons, small unmanned aircraft, etc.). GUI updates to support integration with MDAO frameworks must be completed. Documentation and unit testing of the full API will be completed.

PHASE III DUAL USE APPLICATIONS: Final integration tests with MDAO frameworks will be completed, and the geometry tool will transition into use with NAWCAD MEAD engineers, and other design groups in government and industry.

Geometry modeling for aircraft conceptual design is needed across industry for both defense and commercial applications. A geometry tool capable of direct integration with MDAO frameworks could be valuable to many private sector design groups.

### REFERENCES:

1. McDonald, R. (2016). Advanced Modeling in OpenVSP. 16th AIAA Aviation Technology, Integration, and Operations Conference. <https://doi.org/10.2514/6.2016-3282>.
2. Gary, A. & McDonald, R. (2015). Parametric Identification of Surface Regions in OpenVSP for Improved Engineering Analysis. 53rd AIAA Aerospace Sciences Meeting. <https://doi.org/10.2514/6.2015-1016>.

KEYWORDS: Aircraft Design; Geometry; Optimization; MDAO; Software; Open Vehicle Sketch Pad; OpenVSP

## VERSION 8

N221-005 TITLE: DIGITAL ENGINEERING - Photonics Integration for Modular Open Systems Approach Avionics Plug-in Modules

OUSD (R&E) MODERNIZATION PRIORITY: Networked C3

TECHNOLOGY AREA(S): Air Platforms;Electronics;Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 photonic plug-in module technology and a modeling approach for designing and packaging air platform digital and analog optical communication avionics.

DESCRIPTION: Current airborne military (mil-aero) core avionics, electro-optic (EO), communications and electronic warfare systems require ever-increasing bandwidths while simultaneously demanding reductions in space, weight, and power. The replacement of shielded twisted pair wire and coaxial cable with earlier generation length-bandwidth product, multimode optical fiber has given increased immunity to electromagnetic interference, bandwidth, throughput, and a reduction in size and weight on aircraft. The effectiveness of these systems hinges on optical communication components that realize large link budget, high dynamic range, and are compatible with the harsh avionic environment [Refs 1, 5-7].

Future avionics digital and analog/radio-frequency (RF) signal transmission rates and frequencies are expected to increase to the point where fiber optics is the only medium with the capacity and low loss for maintaining communications signal integrity. Substantial work has been done in the digital domain to realize 100 Gbps data rates based on shortwave wavelength division multiplexing (SWDM) and coarse wavelength division multiplexing (CWDM) technologies [Refs 8-9]. Generally, SWDM utilizes 50 micrometer core multimode optical fiber and CWDM utilizes single-mode optical fiber for optical interconnection. Optical Multimode 4 (OM4) and Optical Multimode 5 (OM5) optical fiber has been optimized for 100 Gbps and higher SWDM links. Digital links generally use physical contact and non-contact connectors, with no angle polish. In the analog/RF domain there is interest in realizing higher performance intensity modulation with direct detection photonic links based on improvements in fiber pigtailed laser and photodetector, and electro-optic modulator performance [Ref 12]. Phase modulation with interferometric detection type links continues to be of interest for avionics as well [Ref 13]. Analog/RF photonic links generally utilize single-mode fiber (both polarization maintaining and single-core) and physical contact connectors [Refs 14-15]. Dual-core fiber connector and analog/RF photonic link technology is in the early stage of development for balanced photonic links [Refs 16-17].

The ANSI/VITA 46 base standard defines physical features that enable high-speed communication in 3U or 6U backplane-based critical and intelligent embedded computing systems [Ref 18]. The ANSI/VITA 65 OpenVPX System standard uses module mechanical, connectors, thermal, communications protocols, utility, and power definitions provided by specific VPX standards and then describes a series of standard profiles that define slots, backplanes, modules, and standard development chassis [Ref 19]. The ANSI/VITA 66.0 Optical Interconnect on VPX base standard defines a family of blind mate fiber optic interconnects for use with VITA 46 backplanes and plug-in modules [Ref 20]. The ANSI/VITA 67 Coaxial Interconnect on VPXbase standard establishes a structure for implementing blind mate analog

## VERSION 8

coaxial interconnects with VPX backplanes and plug-in module, and to define a specific family of interconnects and configurations within that structure [Ref 21].

Photonics integration on plug-in module innovation is needed to implement 100 Gbps and higher digital fiber optic technology. 100 Gbps fiber optic transceivers generally transmit and receive multi-wavelength optical signals with four wavelengths of light, each operating at 25 Gbps to achieve an aggregate bandwidth of =100 Gbps. Typically, the transceivers are interfaced with differential current mode logic signaling and either single-mode or OM4/OM5 multimode fiber. Analog/RF photonics integration on plug-in module innovation is also needed. Analog/RF photonic links generally include a laser with power supply and electro-optic modulator with bias control circuitry and RF connection transmitter, and a high-speed fiber pigtailed photodetector receiver. The proposed digital and analog/RF photonic plug-in modules must operate over a -40 °C to +95 °C temperature range, and maintain performance upon exposure to typical naval air platform vibration, humidity, temperature, altitude, thermal shock, mechanical shock, and temperature cycling environments [Refs 22-27].

Integrating the disparate interfaces associated with digital and analog/RF photonic components on 3U or 6U plug-in modules will require significant digital engineering research and innovation. Not all of the required connections and interfaces are specified in the ANSI/VITA specifications. Field programmable gate array integration and electro-optic modulator RF and optical signal connections for moving digital and analog signals onto and off of plug-in modules between chassis and through chassis backplanes is required. The developed models should include digital and analog/RF loss budget calculations and the ability to perform analysis of system designs up to 100 Gbps and 100 GHz, respectively. Approaches to fill identified digital and analog/RF photonics technology gaps including packaging and connectors is also needed. Digital engineering research is required to understand how to best utilize the existing CAMEO Systems Modeler tool [Ref 28] and Systems Modeling Language (SysML) [Ref 29] for avionics hardware integration.

**PHASE I:** Using SysML, create the handoff between development board level electrical layouts and photonic component packaging concepts for digital and analog/RF photonic components mounted on the plug-in module level, and the module to backplane and external backplane levels. Identify key risk areas for tracing lower level module design to higher level module level design to realize desired performance and packaging for chassis integration, and mitigate these risks using digital engineering research concepts and modeling tools. Demonstrate computer aided designs of 3U and 6U photonic plug-in modules. The Phase I effort will include prototype plans to be developed under Phase II.

**PHASE II:** Collect research data on plug-in module photonics integration concepts including plug-in module to backplane digital and RF connections. Using digital engineering-based software, model photonic plug-in module and chassis backplane integration of digital and analog/RF components. Optimize the plug-in module designs. Build and test photonic module prototypes to meet avionics digital and analog/RF link performance requirements. Characterize the photonic module prototypes over temperature, and perform highly accelerated life testing. If necessary, perform root cause analysis and remediate circuit and/or packaged transmitter failures. Deliver two 100 Gbps digital modules, one intensity modulated with direct detection analog/RF module, and one phase modulated with interferometric detection module. Deliver the SysML model and the CAD model.

**PHASE III DUAL USE APPLICATIONS:** Finalize the prototype. Verify and validate that the plug-in module operates from -40 °C to +95 °C. Transition to applicable naval platforms.

Commercial avionics and general network Infrastructure sectors could benefit from high-speed fiber optic plug-in modules.

## VERSION 8

### REFERENCES:

1. Binh, L.N. (2017, July 26) Advanced digital optical communications (2nd ed.). CRC Press. ISBN 1482226537. <https://doi.org/10.1201/b18128> <https://www.worldcat.org/title/advanced-digital-optical-communications/oclc/1053852857?referer=br&ht=edition>.
2. AS-3 Fiber Optics and Applied Photonics Committee. (2018, January 23). AS5603A Digital Fiber Optic Link Loss Budget Methodology for Aerospace Platforms. Warrendale: SAE.
3. AS-3 Fiber Optics and Applied Photonics Committee. (2018, January 23). AS5750A Loss Budget Specification for Fiber Optic Links. Warrendale: SAE. <https://seamobilus.sae.org/content/as5750A>.
4. AS-3 Fiber Optics and Applied Photonics Committee. (2018, August 20). ARP6318 Verification of Discrete and Packaged Photonics Technology Readiness. Warrendale: SAE. <https://saemobilus.sae.org/content/arp6318>.
5. Department of Defense. (2019, January 31). MIL-STD-810H: Department of Defense test method standard: Environmental engineering considerations and laboratory tests. [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H\\_55998/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/).
6. Department of Defense. (2019, September 16). MIL-STD-883L: Department of Defense test method standard: Microcircuits. Department of Defense. [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883L\\_56323/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883L_56323/).
7. Department of Defense. (2019, December 03). MIL-PRF-38534L: Performance specification: Hybrid microcircuits, general specification for. Department of Defense. [http://everyspec.com/MIL-PRF/MIL-PRF-030000-79999/MIL-PRF-38534L\\_57123/](http://everyspec.com/MIL-PRF/MIL-PRF-030000-79999/MIL-PRF-38534L_57123/).
8. Cole, C., Petrilla, J., Lewis, D., Hiramoto, K., & Tsumura, E. (2015, November 23). 100G CWDM4 MSA technical specifications: 2km optical specifications (D. Lewis, Ed.). CWDM4-MSA. <http://www.cwdm4-msa.org/wp-content/uploads/2015/12/CWDM4-MSA-Technical-Spec-1p1-1.pdf>.
9. Kolesar, P., King, J., Peng, W., Zhang, H., Maki, J., Lewis, D., Lingle, R., & Adrian, A. (2017, November 6). 100G SWDM4 MSA technical specifications: optical specifications (D. Lewis, Ed.). SWDM. <https://pdf4pro.com/view/100g-swdm4-msa-technical-specifications-18af22.html>.
10. Telecommunications Industry Association. (2009). TIA-492AAAD: Detail Specification for 850-nm laser-optimized, 50  $\mu\text{m}$  core diameter/125- $\mu\text{m}$  cladding diameter class Ia graded-index multimode optical fibers suitable for manufacturing OM4 cabled optical fiber. Telecommunications Industry Association (TIA). <https://standards.globalspec.com/std/1194330/TIA-492AAAD>.
11. Telecommunications Industry Association. (2016, June). TIA-492AAAE: Detail specification for 50- $\mu\text{m}$  core diameter/125- $\mu\text{m}$  cladding diameter class Ia graded-index multimode optical fibers with laser-optimized bandwidth characteristics specified for wavelength division multiplexing. Telecommunications Industry Association. [https://global.ihs.com/doc\\_detail.cfm?&csf=TIA&item\\_s\\_key=00689098&item\\_key\\_date=970301&input\\_doc%20number=TIA%2D492AAAE&input\\_doc\\_title=&org\\_code=TIA](https://global.ihs.com/doc_detail.cfm?&csf=TIA&item_s_key=00689098&item_key_date=970301&input_doc%20number=TIA%2D492AAAE&input_doc_title=&org_code=TIA).
12. Urick, V. J., Williams, K. J., & McKinney, J. D. (2015). Fundamentals of microwave photonics. John Wiley & Sons. <https://doi.org/10.1002/9781119029816>.
13. Urick, V. J., Bucholtz, F., Devgan, P. S., McKinney, J. D., & Williams, K. J. (2007). Phase modulation with interferometric detection as an alternative to intensity modulation with direct detection for analog-photonics links. IEEE transactions on microwave theory and techniques, 55(9), 1978-1985. <https://doi.org/10.1109/TMTT.2007.904087>.
14. Noda, J., Okamoto, K., & Sasaki, Y. (1986). Polarization-maintaining fibers and their applications. Journal of Lightwave Technology, 4(8), 1071-1089. <https://doi.org/10.1109/JLT.1986.1074847>.
15. Nagase, R., Abe, Y., & Kihara, M. (2017, August). History of fiber optic physical contact connector for low insertion and high return losses. In 2017 IEEE HISTORy of ELectrotechnology

## VERSION 8

- CONference (HISTELCON) (pp. 113-116). IEEE.  
<https://doi.org/10.1109/HISTELCON.2017.8535630>.
16. Abe, Y., Shikama, K., & Asakawa, S. (2017). Multi-core fiber connector technology for low-loss physical-contact connection. *NTT Tech. Rev.*, 15(6), 1-6. <https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201706fa6.pdf&mode=show>.
  17. Diehl, J., Nickel, D., Hastings, A., Singley, J., McKinney, J., & Beranek, M. (2019, November). Measurements and discussion of a balanced photonic link utilizing dual-core optical fiber. In 2019 IEEE Avionic and Vehicle Fiber-Optics and Photonics Conference (pp.1–2). IEEE.  
<https://doi.org/10.1109/AVFOP.2019.8908161>.
  18. Standards Organization. (2019). ANSI/VITA 46.0-2019: VPX: Baseline. VMEBUS International Trade Association (VITA). <https://www.vita.com/Standards>.
  19. VITA Standards Organization. (2019). ANSI/VITA 65.0-2019: OpenVPX system. VMEBUS International Trade Association (VITA). <https://www.vita.com/Standards>.
  20. VITA Standards Organization. (2019). ANSI/VITA 66.0-2019: VPX: Optical interconnect on VPX - base standard. VMEBUS International Trade Association (VITA).  
<https://www.vita.com/Standards>.
  21. VITA Standards Organization. (2019). ANSI/VITA 67.0-2019: VPX: Coaxial interconnect - base standard. VMEBUS International Trade Association (VITA). <https://www.vita.com/Standards>.
  22. Department of Defense. (2019, September 16). MIL-STD-883-1: Department of Defense test method standard: Environmental test methods for microcircuits: Part 1: Test methods 1000-1999 (Method 1010.9 Temperature Cycling). [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1\\_56324/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1_56324/).
  23. Department of Defense. (2019, September 16). MIL-STD-883-2: Department of Defense test method standard: Mechanical test methods for microcircuits: Part 2: Test methods 2000-2999 (Method 2001.4 Constant acceleration). [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-2\\_56325/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-2_56325/).
  24. Department of Defense. (2019, September 16). MIL-STD-883-1: Department of Defense test method standard: Environmental test methods for microcircuits: Part 1: Test methods 1000-1999 (Method 1001 Barometric pressure, reduced (altitude operation)). [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1\\_56324/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1_56324/).
  25. Department of Defense. (2019, September 16). MIL-STD-883-1: Department of Defense test method standard: Environmental test methods for microcircuits: Part 1: Test methods 1000-1999 (Method 1014.17 Seal). [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1\\_56324/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1_56324/).
  26. Engineering Department. (1997, April). EIA/JESD22-A101-B: EIA/JEDEC standard: Test method A101-B: Steady state temperature-humidity bias life test. Electronic Industries Association. <https://studyres.com/doc/22624089/jesd22-a101b>.
  27. DLA Land and Maritime. (2019, September 16). MIL-STD-883-1: Department of Defense test method standard: Environmental test methods for microcircuits: Part 1: Test methods 1000-1999 (Method 1005.11 Steady-state life). [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1\\_56324/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883-1_56324/).
  28. The Object Management Group. (n. d.). What is SYSML? OMG Systems Modeling Language. Retrieved March 17, 2021, from <https://www.omgsysml.org/what-is-sysml.htm>.
  29. Bassinan, O., & Boyden, W. (2020). High Speed Vertical Cavity Surface Emitting Laser (VCSEL).” Navy SBIR Program, Navy STTR 20.B - Topic N20B-T027.  
[https://www.navysbir.com/n20\\_B/N20B-T027.htm](https://www.navysbir.com/n20_B/N20B-T027.htm).

KEYWORDS: Digital Engineering; Fiber Optics; Photonics; Modular Open Systems Approach; Plug-in Module; 100 Gigabits per second

## VERSION 8

N221-006 TITLE: Room-Temperature Filler for Honeycomb Repairs

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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

OBJECTIVE: Develop and demonstrate a lightweight honeycomb core filler for repairs with a short, room room-temperature cure.

DESCRIPTION: Current composite honeycomb repairs rely on either epoxy fill, higher temperature cure (150-160° F; 65.56–71.11 °C) syntactic foams, or 7-day room-temperature cures of syntactic foam. These options have drawbacks, including long times to complete the repair, additional required equipment for controlling/monitoring the cure, and increased resultant weight for epoxy fill repairs. In addition, syntactic foams were designed for battlefield or non-aviation applications and lack the target room-temperature cure duration and required mechanical performance. Composite honeycomb repairs need to be simplified and streamlined to reduce repair turnaround time and necessary support equipment. Reducing the time to cure can drastically improve the rate at which repairs are completed, increasing fleet readiness. As an added benefit, development and qualification of a new repair material will offer an additional solution for repairs.

A new lightweight, streamlined composite honeycomb repair material and process using a novel lightweight, structural filler formulation is sought to reduce the time required for honeycomb repairs. The proposed material can take advantage of various matrix chemistries and fillers [Ref 1]. The repair material would be expected to meet threshold requirements, threshold mechanical properties, and target requirements.

Threshold requirements include, but are not limited to:

- Maximum of 24 hour cure at room temperature 70 °F (27 °C)
- Compatibility with aluminum, Nomex, and polyurethane foam cores
- Maximum exothermic temperature during cure not to exceed 200 °F (93.3 °C)
- Minimum 15 minute pot life
- Maximum density of 0.8 g/cc
- Shelf life of 12 months at 77 °F (25 °C)

Threshold mechanical properties include, but are not limited to:

- Compressive strength of 8 ksi at 77 °F (25 °C) by ASTM D695 [Ref 2]
- Lap shear of 700 psi at 77 °F (25 °C) by ASTM D1002 [Ref 3]
- Retention of 50 % of compressive strength at 180 °F (83 °C)

Target requirements include, but are not limited to:

- 1 hr cure before sanding at room temperature 70 °F (27 °C)
- Retention of greater than 15% compressive strength at 350 °F (177 °C)
- Ability to cure at temperatures down to 32 °F (0 °C) without added heat
- Greater than 15 min pot life
- Density 0.5 g/cc or lower

PHASE I: Develop novel composite honeycomb filler formulations and screen candidate formulations for feasibility. This assessment can include cure kinetics (maximum exothermic temperature, cure time, pot life) and density to identify the most promising candidate formulations. The Phase I effort will include prototype plans to be developed under Phase II.

## VERSION 8

PHASE II: Develop and provide a prototype repair process (suitable for a Depot or I Level repair) using the developed repair material in Phase I. Complete a repair with a minimum size of 3 inches in diameter and 1.5 inches in thickness on a representative part with the developed honeycomb filler. Conduct, in coordination with the Government, mechanical and physical testing that includes a limited set of screening tests sufficient to ensure acceptable properties. Demonstrate reduction in overall cure time and compatibility with common naval aviation honeycomb materials.

PHASE III DUAL USE APPLICATIONS: Generate data for full qualification and validate the repair filler material and the repair technique. Repair instructions for Depot or I Level honeycomb repairs will be developed and provided. Transition the technology to applicable Navy Depot.

Honeycomb repair is applicable to composites outside of the aerospace industry. The automotive, as well as the marine industry, use honeycomb or filled-composite structures. A repair material that is effective across multiple industries is possible.

### REFERENCES:

1. Afolabi, L. O., Ariff, Z. M., Hashim, S. F. S., Alomayri, T., Mahzan, S., Kamarudin, K. A., & Muhammad, I. D. (2020). Syntactic foams formulations, production techniques, and industry applications: a review. *Journal of Materials Research and Technology*, 9(5), 10698-10718. <https://doi.org/10.1016/j.jmrt.2020.07.074>.
2. Subcommittee D20.10 on Mechanical Properties. (2015). ASTM D695-15: Standard test method for compressive properties of rigid plastics. ASTM International. <https://doi.org/10.1520/D0695-15>.
3. Subcommittee D14.80 on Metal Bonding Adhesives. (2019). ASTM D1002-10: Standard test method for apparent shear strength of single-lap-joint adhesively bonded metal specimens by tension loading (metal-to-metal). ASTM International. <https://doi.org/10.1520/D1002-10R19>.

KEYWORDS: Composites; Honeycomb; Repair; Lightweight; Room temperature; Filler



## VERSION 8

N221-007 TITLE: Data-Driven Physics-Based Modeling Tools to Determine Effective Mechanical Properties of As-Built Composite Structures

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML)

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

OBJECTIVE: Develop a software toolkit to automate the generation of nonlinear, anisotropic mechanical properties for as-built composite structures, including the effects of defects, to accelerate finite element (FE) analysis for fleet repairs and aircraft production non-conformal dispositions.

DESCRIPTION: Advanced rotors for vertical lift aircraft and wings on many U.S. Navy fixed-wing aircraft are complex assemblies made primarily from thermoset composites (e.g., IM7/977-3). Full-scale fatigue tests are frequently required to qualify and certify these critical safety items for a calculated number of flight hours. The selected part chosen for testing may have deliberate seeded flaws and/or severe manufacturing defects to capture the worst damage/condition expected in service. After these weakened parts survive the full-scale fatigue tests, applied knockdown factors further reduce the risk of fatigue failure. Even though the strength safety margin for a given part could be sufficiently high, when service damage occurs, engineers have very tight repair limits, and few options, due to the fatigue life constraint. Local stress distributions, and in-situ mechanical properties of the composite parts, have a significant influence on fatigue life and residual strength, and are very complex to predict, especially for the thick (0.5 in./1.27 cm or greater) laminate composites.

A potential remedy to establish additional cost-effective repair options is to implement a data-driven, physics-based, modeling approach by analyzing the parts in the as-built condition with their own unique configuration, including manufacturing defects and in-service damages. Examples of manufacturing defects are wrinkles, marcols, foreign object debris, porosities/voids, and delamination. In-service damages could include impact, maintenance induced, and heat or ballistic damage.

In addition to an accurate FE mesh representation of the as-built component, the other crucial analysis requirement is the assignment of accurate in-situ (nonlinear) mechanical properties to the FEs. Typical mechanical properties for laminate composite FE analyses (FEAs) use linear orthotropic values based on coupon testing (versus as-built structures). As a result, strain gauge values monitored during full-scale tests can differ substantially from FEA results. These differences between strain gauge results and strain/stress analysis predictions deserve scrutiny when considering repair options. Innovative advancements in computerized tomography (CT) scan image processing coupled with advanced micro-meso-macro mechanics modeling can be utilized to yield not only more representative anisotropic mechanical properties, but also a more accurate stress/residual strength analysis of the real structures.

The Navy seeks to develop a software toolkit that can automate the process to generate in-situ, nonlinear, anisotropic effective mechanical properties using CT scans of as-built composite parts. The critical size and boundary conditions of the representative volume element (RVE) must be consistent with the material system's inhomogeneity, scan resolution, and fidelity of the intended FE mesh. The scan resolution should be sufficiently high enough to capture the appropriate length scale(s) associated with material system components (e.g., ply thickness/orientation, fiber path/bundle/volume, fiber/resin, and adhesive interfaces) and manufacturing defects (e.g., porosities/voids, wrinkles, delamination, and fiber waviness). The most critical defects include combinations of wrinkles, porosities/voids, and resin-rich or adhesive-rich zones, which should be captured by the model with an effective relationship to the FE mesh and intended analysis. The proposed toolkit must also account for material degradation due to repeated loadings and Hot/Wet (H/W) operating environments. The generated quasi-static and dynamic-effective mechanical properties (stiffness, strength, and strain energy release rate) must be compatible with

## VERSION 8

different 2-D and 3-D FE types including shell/plate and tetra-/hexahedral elements. Since the data volume of the CT scans could be very huge (larger than one terabyte) for a full-scale component, speed and accuracy issues relating to data acquisition, image processing, and data storage and retrieval must also be addressed, including the use of machine learning (ML) and computer vision techniques.

PHASE I: Demonstrate technical feasibility of the proposed concept to develop a computationally efficient, multiscale, physics-based, modeling toolkit coupled with CT-scanned data, ML, and computer vision techniques to generate in-situ, quasi-static, and dynamic effective mechanical properties (stiffness, strength, and strain energy release rate) for as-built, thick laminate composite structures, including effects of defects, repeated loadings, and expected H/W operating environments. Demonstrate the proposed workflow to auto-populate the input data for different 2-D and 3-D FE meshes, including various element sizes and types to support progressive damage analysis of thick laminate composite structures. Develop a verification and validation (V & V) test plan for the proposed concept, including, at a minimum, the use of Digital Image Correlation (DIC).

PHASE II: Perform CT scan of test coupons/components representative of a structural component with manufacturing defects (e.g., L-shape). Develop algorithms for fast CT image processing, automated feature extraction, and identification/classification with ML techniques, and data storage and retrieval. Demonstrate the generation of a localized FE mesh from CT scan data capturing ply orientations and manufacturing defects. Demonstrate the integrated process utilizing the developed multiscale, physics-based, modeling toolkit and CT-scanned data to predict the in-situ, quasi-static, and dynamic effective mechanical properties (stiffness, strength, and strain energy release rate) for a structural representative thick laminate composite test component including effects of defects and operating environments. Demonstrate the auto-populated input data functionality for different 2-D and 3-D meshes. Conduct testing in accordance with the V & V test plan developed in Phase I to correlate with the predicted results.

PHASE III DUAL USE APPLICATIONS: Finalize the prototype modeling-toolkit and ensure usability for the end user. Perform final testing to demonstrate the toolkit's ability to support analysis of a fleet repair or solve a production issue on a large-scale and relevant platform part.

Commercial aviation uses similar structures and has a similar need for more capable analysis toolkits to analyze repairs and production issues. This capability might also find use in the wind turbine industry, as the blades are large composite structures.

### REFERENCES:

1. Avril, S., Bonnet, M., Bretelle, A. S., Grédiac, M., Hild, F., Ienny, P., Latourte, F., Lemosse, D., Pagano, S., Pagnacco, E., & Pierron, F. (2008, July 25). Overview of identification methods of mechanical parameters based on full-field measurements. *Experimental Mechanics*, 48(4), 381. <https://doi.org/10.1007/s11340-008-9148-y>.
2. Rahmani, B., Villemure, I., & Levesque, M. (2014). Regularized virtual fields method for mechanical properties identification of composite materials. *Computer Methods in Applied Mechanics and Engineering*, 278, 543-566. <https://doi.org/10.1016/j.cma.2014.05.010>.
3. Straumit, I., Lomov, S., & Wevers, M. (2015). 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*, 69, 150–158. <https://doi.org/10.1016/j.compositesa.2014.11.016>.
4. Makeev, A., Seon, G., Nikishkov, Y., Nguyen, D., Mathews, P., & Robeson, M. (2016, May 17-19). Analysis methods improving confidence in material qualification for laminated composites [Paper presentation]. Proceedings of the American Helicopter Society 72nd Annual Forum, West Palm Beach, FL, United States.

## VERSION 8

[https://www.researchgate.net/publication/303562174\\_Analysis\\_Methods\\_Improving\\_Confidence\\_in\\_Material\\_Qualification\\_for\\_Laminated\\_Composites](https://www.researchgate.net/publication/303562174_Analysis_Methods_Improving_Confidence_in_Material_Qualification_for_Laminated_Composites).

5. Nikishkov, Y., Seon, G., Makeev, A., & Shonkwiler, B. (2016, March 15). In-situ measurements of fracture toughness properties in composite laminates. *Materials and Design*, 94, 303-313. <https://doi.org/10.1016/j.matdes.2016.01.008>.
6. Seon, G., Makeev, A., Cline, J., & Shonkwiler, B. (2015, September 29). Assessing 3D shear stress-strain properties of composites using Digital Image Correlation and finite element analysis based optimization. *Composites Science and Technology*, 117, 371-378. <https://doi.org/10.1016/j.compscitech.2015.07.011>.
7. Lambert, J., Chambers, A. R., Sinclair, I., & Spearing, S. M. (2012, January 18). 3D damage characterisation and the role of voids in the fatigue of wind turbine blade materials. *Composites Science and Technology*, 72(2), 337-343. <https://doi.org/10.1016/j.compscitech.2011.11.023>.
8. Kim, H. J., & Swan, C. C. (2003). Algorithms for automated meshing and unit cell analysis of periodic composites with hierarchical tri-quadratic tetrahedral elements. *International Journal for Numerical Methods in Engineering*, 58(11), 1683-1711. <https://doi.org/10.1002/nme.828>.
9. Raju, B., Hiremath, S. R., & Mahapatra, D. R. (2018). A review of micromechanics based models for effective elastic properties of reinforced polymer matrix composites. *Composite Structures*, 204, 607-619. <https://doi.org/10.1016/j.compstruct.2018.07.125>.
10. Bargmann, S., Klusemann, B., Markmann, J., Schnabel, J. E., Schneider, K., Soyarslan, C., & Wilmers, J. (2018). Generation of 3D representative volume elements for heterogeneous materials: A review. *Progress in Materials Science*, 96, 322-384. <https://doi.org/10.1016/j.pmatsci.2018.02.003>.
11. Naresh, K., Khan, K. A., Umer, R., & Cantwell, W. J. (2020). The use of X-ray computed tomography for design and process modeling of aerospace composites: a review. *Materials & Design*, 190, 108553. <https://doi.org/10.1016/j.matdes.2020.108553>.
12. Dutra, T. A., Ferreira, R. T. L., Resende, H. B., Guimarães, A., & Guedes, J. M. (2020). A complete implementation methodology for Asymptotic Homogenization using a finite element commercial software: preprocessing and postprocessing. *Composite Structures*, 245, 112305. <https://doi.org/10.1016/j.compstruct.2020.112305>.
13. Nsengiyumva, W., Zhong, S., Lin, J., Zhang, Q., Zhong, J., & Huang, Y. (2021). Advances, limitations and prospects of nondestructive testing and evaluation of thick composites and sandwich structures: A state-of-the-art review. *Composite Structures*, 256, 112951. <https://doi.org/10.1016/j.compstruct.2020.112951>.
14. Thor, M., Sause, M. G., & Hinterhölzl, R. M. (2020). Mechanisms of origin and classification of out-of-plane fiber waviness in composite materials—A review. *Journal of Composites Science*, 4(3), 130. <https://doi.org/10.3390/jcs4030130>.
15. Zambal, S., Eitzinger, C., Clarke, M., Klintworth, J., & Mechin, P. Y. (2018, July). A digital twin for composite parts manufacturing: Effects of defects analysis based on manufacturing data. In 2018 IEEE 16th International Conference on Industrial Informatics (INDIN) (pp. 803-808). IEEE. <https://doi.org/10.1109/INDIN.2018.8472014>.
16. Badran, A., Marshall, D., Legault, Z., Makovetsky, R., Provencher, B., Piché, N., & Marsh, M. (2020, September 8). Automated segmentation of computed tomography images of fiber-reinforced composites by deep learning. *Journal of Materials Science* 55, 16273–16289. <https://doi.org/10.1007/s10853-020-05148-7>.
17. Fritz, N. K., Kopp, R., Nason, A. K., Ni, X., Lee, J., Stein, I. Y., Kalfon-Cohen, E., Sinclair, I., Spearing, S. M., Camanho, P. P., & Wardle, B. L. (2020). New interlaminar features and void distributions in advanced aerospace-grade composites revealed via automated algorithms using micro-computed tomography. *Composites Science and Technology*, 193, 108132. <https://doi.org/10.1016/j.compscitech.2020.108132>.

## **VERSION 8**

**KEYWORDS:** Composites; Finite Element Analysis; Damage Progression; Material Characterization; Manufacturing Defects; Composite Repairs; Computed Tomography

## VERSION 8

N221-008 TITLE: Innovative Approaches to Reducing the Complexity and Increasing Sustainability of Linkless Ammunition Loading System III

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Weapons

OBJECTIVE: Identify and demonstrate system innovative approaches to the Linkless Ammunition Loading System III (LALS III) to increase the system's reliability and availability.

DESCRIPTION: The M61A1 and M61A2 gun systems installed on the legacy and super Hornet F/A-18 are loaded using the LALS III, consisting of a system of gears and conveyors that are complicated to utilize and maintain. There have been several attempts to increase the Mean Time Between Failure (MTBF). However, with the incorporated changes the system still has a high-failure rate for several components (e.g., the conveyor assembly, aircraft interchange unit, and chain ladder assembly) as identified by Conventional Ordnance Discrepancy Reports (CODR). This high-failure rate causes mission delays and an increase to the maintenance workload for the fleet. These components are all complex parts of the overall conveyor system that moves ammunition throughout the LALS III. When connected to the aircraft or the ammunition transfer system to load or download ammunition in and out of the LALS III, there are several sequential steps necessary for the system to function properly. Severe damage and timing issues occur to these components if one step is missed or done out of order. Potential improvements include: (a) an internal timing and tension function to remove human error from the equation, and (b) improvements to the conveyor assembly, aircraft interchange unit, and chain ladder assembly to make them more robust to handle the rigors of the aircraft carrier environment, Forward Operating Bases, and decrease maintenance complexity. Any materials considered should be all-weather, corrosion resistant, suffer no adverse effects from contact with solvents, lubricants, or oils, and be compatible in a Hazards of Electromagnetic Radiation to Ordnance (HERO) environment. The overall goal is to increase the overall availability, sustainability, and readiness.

PHASE I: Define, develop, and demonstrate the feasibility of innovative concepts and procedures increasing the reliability of failed components of the LALS III. Use CODR data to analyze high-failure areas and evaluate failed components of the LALS III. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Refine the conceptual design and develop a prototype. Perform testing of prototype to demonstrate their effectiveness.

PHASE III DUAL USE APPLICATIONS: Integrate solutions in a LALS III. Support operational assessment of the prototype design solutions by a squadron prior to full-scale fielding.

The improvements to the LALS III could potentially be modified to fit other ammunition conveyor units or commercial conveyor assemblies. The improved solutions could be sold to manufacturing processes to increase their reliability and decrease maintenance requirements.

### REFERENCES:

1. United States Government Accountability Office. (2020, January). Defense acquisitions: Senior leaders should emphasize key practices to improve weapon system reliability (GAO-20-151). United States Government Accountability Office. <https://www.gao.gov/assets/710/706781.pdf>.
2. Glowacki, B. (2001). Ammunition loading. NAVEDTRA 14313: Aviation ordnanceman (Ch. 7, pp. 7-1-7-24). Naval Education and Training Professional Development and Technology Center. [https://www.globalsecurity.org/military/library/policy/navy/nrtc/14313\\_ch7.pdf](https://www.globalsecurity.org/military/library/policy/navy/nrtc/14313_ch7.pdf).

## **VERSION 8**

KEYWORDS: Linkless Ammunition Loading System III (LALS III); 20mm Ammunition; Weapons Unloading; Weapons Loading; Weapons Handling; Linkless System

## VERSION 8

N221-009 TITLE: Automated System to Assist in Gauge Block Calibration

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML);Autonomy

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Design and develop an automated system to assist in the gauge block calibration process.

DESCRIPTION: The Navy Primary Standards Laboratory (NPSL) and the Navy Calibration Laboratory Lakehurst (LAL) provide specialized calibration support throughout the Navy. One of the primary calibration procedures they perform is gauge block calibration. This process involves calibrating a precise length measurement machine using calibrated gauge blocks. The block, or blocks, being used must be placed on a precise position on the measuring machine. Measuring machines currently in use at the facilities include the Labmaster Universal Measuring System Model 175, and the Precimar Models 130B-24 and 130B-16. As the task is currently performed by hand, the operators regularly run into an issue where the heat from their hands causes the blocks to expand, and affects the blocks' dimensions. The operators handle the gauge blocks with gloves in order to mitigate this effect, but enough heat is still transferred to affect the measurements. When this occurs, blocks have to be left sitting untouched for up to a few hours to return to normal dimensions. This can introduce delays and increased costs.

This SBIR topic seeks to develop an automated system that can perform some or all of this calibration process. This would greatly reduce required operator time, freeing up resources for alternate tasks. This would also reduce any delays, as tasks using the system could be run consecutively.

In particular, the system must meet the following block and measurement device specifications:

- Block sizes range from < 1 in. (< 2.54 cm) to approximately 24 in. (60.96 cm) in length.
- Blocks are stored in several standard containers near the measurement device.
- Blocks must be placed on a planar surface in a designated position with a minimum accuracy of 0.03125 in. (0.07937 cm) and an ideal accuracy of 0.01 in. (0.0254 cm).
- The measurement device has a free working dimension of 1.5 in. by 3 in. (3.81 cm by 7.62 cm). The solution must not make contact with the measurement device outside of this area.
- The system should capture the output from the measurement device.
- Total thermal output of the system should prevent raising the temperature of the room more than 0.2 °F (-17.66 °C) to maintain repeatable calibrations.

While there are precision robotic systems in other domains such as medical robotics [Ref 4], none have been evaluated for use in this type of situation, including the accuracy requirements and the ability to handle the wide range of gauge block sizes. This calibration procedure requires precise manipulation and placement of these blocks within the test stand. The key barrier is ensuring that the process is repeatable and reliable to operate without user supervision while still meeting all calibration process requirements. If successful, this solution could be adapted to additional calibration labs or other similar processes.

PHASE I: Design and develop an initial concept that can meet the stated requirements for the calibration system. Demonstrate feasibility of the system concept to perform the calibration procedure subject to those requirements. The system concept does not have to perform all steps in the procedure, it must only demonstrate that the steps are likely to work and meet the acceptance criteria through benchtop tests. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a working prototype. Integrate the functions demonstrated in Phase I into a working system that meets all performance requirements. Demonstrate the prototype in a lab or live environment.

## VERSION 8

PHASE III DUAL USE APPLICATIONS: Perform final testing for verification of requirements by the calibration stakeholders. Following success in final tests, the system will be transitioned into use at naval calibration facilities.

Companies that develop complex mechanical systems, such as defense contractors, and university research laboratories utilize metrology facilities to accurately measure mechanical components. As gauge blocks are a commonly utilized method of calibrating measurement equipment, an automated system that can perform the calibration task would be a valuable acquisition for any of those companies and groups. In addition, though the goal of this topic is to develop a system targeted at the requirements of the described calibration task, the precise manipulation and repeatability requirements would have potential use in many applications where an automated system needs to precisely manipulate small objects, such as pick-and-place operations and assembly portions of manufacturing processes.

### REFERENCES:

1. Doiron, T. & Beers, J. (n.d.). The gauge block handbook. National Institute of Standards and Technology. <https://emtoolbox.nist.gov/Publications/NISTMonograph180.pdf>.
2. Pratt & Whitney. (2012). Labmaster universal measuring system. Pratt & Whitney. <https://pdf.directindustry.com/pdf/pratt-whitney/labmaster-universal-model-175/25150-463581.html>.
3. Mahr. (n.d.). Precimar 130B-24: Gage block comparator 130B-24. Mahr. <https://metrology.mahr.com/en-int/products/article/2150076-endmasspruefstand-precimar-130b-24>.
4. Beasley, R. A. (2012, August 12). Medical robots: Current systems and research directions (F. Janabi-Sharifi, Ed.). Journal of Robotics. Hindawi. <https://doi.org/10.1155/2012/401613>.

KEYWORDS: Automation; Metrology; Robotics; Calibration; Robotic Manipulation; Robotic Grasping



## VERSION 8

N221-010 TITLE: Magnetometer Classification of Underwater Objects

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platforms

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

**OBJECTIVE:** Design and develop a system using existing sensors and real-time signal-processing algorithms for classification of underwater objects.

**DESCRIPTION:** Modern frontline submarines pose a threat to maritime strategy and naval operations. The proliferation of acoustic quieting techniques has severely decreased the detection range of passive acoustic sensors. Active acoustic sensors can provide longer range, however they do not provide classification of the target.

New compact sensors provide an opportunity to develop improved real-time detection, target parameter extraction, target localization, prosecution/tracking, and classification of underwater objects. Advanced signal processing techniques may generate classification from a variety of sources, including magnetometers; magnetic dipoles; and extremely low frequency (ELF), ultralow frequency (ULF), electric fields (E-Fields); or other sources of opportunity, such as magnetotelluric or very low frequency radio wave sources. The desired end-product is a system for classification of underwater objects consisting of the magnetometers (< 4) and an open architecture, software module with the necessary algorithms to process sensor data and conduct data fusion for classification. It will be requested for the software to process the data in real time, that is, capable of providing a result analysis and display of the data while data is being taken. The magnetometer will be an onboard system vice a towed magnetometer. Developed software must be compatible with platform architecture, i.e., Joint Mission Planning System (JMPS).

Examples of features the system should account for include, but are not limited to:

- geo-location coordinates
- date and time stamp
- platform altitude
- graphical user interface
- probability of detection
- false alarm rate
- geologic, geo-atmospheric, oceanic, and platform noise characteristics
- data fusion

If the target is identified as a mobile submerged target, the following features should be identified:

- target course, speed, and depth parameters
- target length
- target diameter
- target screw turn rate

## VERSION 8

- target screw configuration (i.e., 5-bladed screw)

If the target is determined to be a submarine, the following features should be identified:

- submarine sail length and location
- submarine type

Magnetic Anomaly Detection (MAD) sensor metrics include, but are not limited to:

- noise floor: < 0.35 pT/rt Hz from 0.01–100 Hz
- magnetometer: able to operate in all of Earth's field orientations and magnitudes
- magnetometer: not sensitive to motion-induced measurement errors or the MAD system must be able to compensate for motion-induced measurement errors
- cost per system: Objective < \$2,000, Threshold < \$10,000
- volume: < 100 cc (sensor Head), < 500 cc (electronic module)
- power: Objective < 1 W, Threshold < 5 W

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor 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 a conceptual design of real-time, open architecture software signal processing algorithms to achieve classification of underwater objects using commercial off-the-shelf magnetometer sensors onboard rotorcraft. The Phase I effort will include prototype plans to be developed under Phase II. Awardees should provide NAVAIR a white paper of the developed or implemented theory.

PHASE II: Develop a candidate prototype for real-time magnetometer sensor and signal processing for classification of underwater objects using an open architecture software. Perform algorithm testing and performance validation using simulated processed signals and actual data. Refine the software, integrate it with the proposed sensors and a commercial magnetometer in the laboratory (or other location), and demonstrate the system classification performance. Use of fictitious classification data is acceptable.) Conduct a flight test to demonstrate the prototype magnetometer sensor and signal processing for classification of underwater objects against a target of opportunity (surface ship if the target of opportunity is not available). Demonstration parameters should be approved by the Technical Point of Contact (TPOC). Deliver the classification of underwater objects prototype to the Government for use as a laboratory demonstration model.

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

PHASE III DUAL USE APPLICATIONS: Final transition of this project will involve implementation of the software to JMPS or other hardware architecture specific to the platform. In addition, noise models tailored to the requested platform should be developed. Final testing will involve compilation of real data in the platform, processing of the data in the software, analysis of software results with those simulated with probability models created by software, and measurement of software effectiveness. End results should provide detection, localization, and classification of a target with a signal of around 100 to 101 pT/rt Hz.

## VERSION 8

Development of a magnetic detection capability that can be implemented and, potentially, sold to different airborne platforms for the detection of unknown magnetic targets hidden underground or at sea. Possible industries include military, security, atmospheric, and surveillance.

### REFERENCES:

1. Ben-Kish, A., & Romalis, M. V. (2010). Dead-zone-free atomic magnetometry with simultaneous excitation of orientation and alignment resonances. *Physical review letters*, 105(19), 193601. <https://doi.org/10.1103/PhysRevLett.105.193601>.
2. Bickel, S. H. (1979). Small signal compensation of magnetic fields resulting from aircraft maneuvers. *IEEE Transactions on aerospace and electronic systems*, (4), 518-525. <https://doi.org/10.1109/TAES.1979.308736>.
3. Shah, V., Knappe, S., Schwindt, P. D., & Kitching, J. (2007). Subpicotesla atomic magnetometry with a microfabricated vapour cell. *Nature Photonics*, 1(11), 649-652. <https://www.nist.gov/publications/subpicotesla-atomic-magnetometry-microfabricated-vapour-cell>.
4. Department of Defense. (2006, February 28). DoD 5220.22-M National Industrial Security Program Operating Manual (Incorporating Change 2, May 18, 2016). Department of Defense. <https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>.

KEYWORDS: Electromagnetic Detection; Underwater Object Classification; Signal Processing; Rotorcraft; Magnetometer; Object Vector Characterization

## VERSION 8

N221-011 TITLE: Low-Cost, Large, Multidimensional, High-Sensor-Density, Collapsible Arrays

OUSD (R&E) MODERNIZATION PRIORITY: 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 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 large, multidimensional, high-sensor-density, collapsible arrays compatible with A-size sonobuoy dimensions and applications.

DESCRIPTION: The Navy requires high-gain arrays for both passive and active sonar due to continued submarine quieting. Technically, this implies designs with increased apertures, dimensionality, and numbers of elements. However, the fundamental constraint of an A-size sonobuoy will remain in place for the foreseeable future. Traditional sonobuoys have evolved from single-line, multi-element arrays to more complex two-dimensional planar arrays (e.g., the Air-Deployable Acoustic Receiver (ADAR)). Rather than seeking an incremental path of increasing the efficiency of discrete element foldable structures, this SBIR topic seeks radical new solutions for achieving high-gain, three-dimensional, multi-element array structures capable of fitting within an 18 in. length and 4.75 in diameter section of an A-size sonobuoy. Of interest, but not required, is the use of collapsible, water-inflatable structures or novel material methods to create a structural framework. The solution should then enlist techniques to maximize use of the array's structure to support stable sensing elements of high density. The over-sampled volumetric array should increase array gain, increase flexibility in controlling sidelobes, and increase adaptivity across operating bands. Efficiency in electrical connectivity (if needed), power use, stability of the structure when deployed, sensitivity of the elements, and overall weight are important design factors to consider as well. The overall goal of this topic is to identify and implement technology that incorporates novel mechanical and sensor designs to exploit as much of the array's structure as possible to greatly increase sonobuoy sensing capability.

The performance objectives:

- Packaged size: < 18 in. (45.72 cm) of the A-size canister
- Numbers of elements: > 100
- Element frequency response: up to 7.5 kHz
- Sensitivity—Noise: limited sea -state zero (SS0) noise
- Weight: < 20 lb (9.07 kg)

PHASE I: Develop a conceptual design for a volumetric array. Since there is no physical aperture requirement, demonstrate the feasibility of the design relative to an existing A-size sonobuoy aperture and expected performance estimated from open sources. Identify technological and reliability challenges of the design and propose viable risk mitigation strategies. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a specific set of sonobuoy array requirements satisfying critical mission(s) needs. Adapt the Phase I conceptual design to satisfy those requirements. Then design, fabricate, and deliver an

## VERSION 8

array subsystem prototype capable of meeting the requirements. Test and fully characterize the system prototype.

PHASE III DUAL USE APPLICATIONS: Adapt the Phase II design into existing A-size sonobuoy architecture(s); designing, fabricating, and delivering a sonobuoy prototype capable of meeting the requirements; test and fully characterize the system prototype.

The development of this technology will have application to the oceanographic community and oil exploration industry.

### REFERENCES:

1. Suhey, J. D., Kim, N. H., & Niezrecki, C. (2005). Numerical modeling and design of inflatable structures—application to open-ocean-aquaculture cages. *Aquacultural Engineering*, 33(4), 285-303. <https://doi.org/10.1016/j.aquaeng.2005.03.001>.
2. Budynas, R. G., & Nisbett, J. K. (2015). *Shigley's Mechanical Engineering Design*. New York: McGraw-Hill. <https://www.amazon.com/Shigleys-Mechanical-Engineering-Richard-Budynas/dp/933922163X>.
3. Holler, R.A., Horbach, A.W., & McEachern, J.F. (2008). *The Ears of Air ASW – A History of U.S. Navy Sonobuoys*. Navmar Applied Sciences Corporation. <https://www.worldcat.org/title/ears-of-air-asw-a-history-of-us-navy-sonobuoys/oclc/720627294>.

KEYWORDS: Sonobuoy; Array; ASW; Collapsible; A-size; Structure

## VERSION 8

N221-012 TITLE: Advanced Jam-Resistant Radar Waveforms

OUSD (R&E) MODERNIZATION PRIORITY: 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 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 waveform design approaches that are robust in the presence of barrage noise and deceptive jamming techniques.

DESCRIPTION: Radar electronic protection systems employing traditional static, table-based threat recognition have increasingly limited efficacy against modern electronic warfare systems. However, the software control of many modern radar systems enables dynamic waveform generation and scheduling that significantly expands the available signal use and processing domain. Here we seek to take advantage of that flexibility to design a class of jam-resistant waveforms suitable for surface and air target detection, tracking, and imaging from an airborne radar system. The selection of a particular waveform would be determined by a cognitive, engine-based, radar resource manager and counter electronic attack system using knowledge gained from its perception-action, real-time feedback loop. Among the candidate approaches to be considered are coded waveforms, chaotic waveforms, and noise waveforms. Other techniques optimizing the waveform for target, clutter, and jamming conditions should be considered.

The cognitive control element in this approach should assess the efficacy of waveform choices and capture this information as part of a data record agent that leverages that information to support a jammer technique recognition and inference process. This also should serve as the means of accumulating new knowledge for future model aggregation. The streaming record is envisioned as an object database/ontology that maintains a signal record and linkage-based affiliation of signals and their inferred emitter attributes. The layers should leverage a common data structure to define and maintain a model of each unique jammer response as an evolving knowledge base, support relational assessment of them and their behaviors, support model extensions to accommodate new and anomalous signals, and support constrained collection and dissemination of this information.

Work produced in Phase II may be classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor 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.

## VERSION 8

PHASE I: Develop approaches and demonstrate feasibility of multiple jam-resistant radar waveforms for maritime surveillance and imaging modes, and/or airborne all-aspect search or airborne early warning horizon search. Assess performance impacts of use of these waveforms relative to traditional waveforms in both quiescent and jamming environments. Identify the critical cognitive control elements including the nature of efficacy metrics to be collected and models generated. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop prototype modes for demonstration on a Navy test asset. Based on these results, select and further mature the most promising approaches. Significantly increase the fidelity of the cognitive control element by fully identifying end-to-end functions, and develop a prototype implementation.

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: Complete development, perform final testing, integrate, and transition the final solution to naval airborne radar system.

Civilian uses for both radar and communication system in the presence of unintentional and intentional jamming is possible with this technology. Those potential applications include law enforcement and emergency services communication systems as well as civil aviation communication and radar systems.

### REFERENCES:

1. Akbarpour, A., & Mirzahosseini, D. (2011, September). The anti-jamming capability of phase coded waveform with limited side-lobe level in correlation function. In 2011 12th International Radar Symposium (IRS) (pp. 835-840). IEEE. <https://ieeexplore.ieee.org/document/6042205>.
2. Lukin, K., Vyplavin, P., Yarovoy, S., Kudriashov, V., Palamarchuk, V., Lee, J.-M., Kang, Y.-S., Cho, K.-G., Ha, J.-S., Sun, S.-G., & Cho, B.-L. (2011, September). 2D and 3D imaging using S-band noise waveform SAR. In 2011 3rd International Asia-Pacific Conference on Synthetic Aperture Radar (APSAR) (pp. 1-4). IEEE. <https://ieeexplore.ieee.org/document/6087063>.
3. Akbarpour, A., & Mirzahosseini, D. (2011, October). Improving range resolution in jammed environment by phase coded waveform. In Proceedings of 2011 IEEE CIE International Conference on Radar (Vol. 1, pp. 226-229). IEEE. <https://ieeexplore.ieee.org/document/6159517>.
4. Lukin, K., Vyplavin, P., Palamarchuk, V., Zemlyaniy, O., Kudriashov, V., & Lukin, S. (2012, September). Capabilities of noise radar in remote sensing applications. In 2012 Tyrrhenian Workshop on Advances in Radar and Remote Sensing (TyWRRS) (pp. 10-17). IEEE. <https://ieeexplore.ieee.org/document/6381095>.
5. Picciolo, M. L., Goldstein, J. S., Settle, T. F., Tinston, M. A., & Schoenig, G. N. (2006, January). Ambiguity function analysis of adaptive colored-noise radar waveforms. In 2006 International Waveform Diversity & Design Conference (pp. 1-6). IEEE. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8321423>.
6. Lukin, K. A. (2006, January). Radar design using chaotic and noise waveforms. In 2006 International Waveform Diversity & Design Conference (pp. 1-5). IEEE. <https://ieeexplore.ieee.org/document/8321486>.

KEYWORDS: Radar; Waveforms; Anti-Jam; Adaptive; Coding; Interference

## VERSION 8

N221-013 TITLE: Development of High-Viscosity Pre-Penetrant Etching Materials

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop high-viscosity pre-penetrant etchant materials for aluminum alloys.

DESCRIPTION: Fluorescent penetrant nondestructive inspection (NDI) processes are utilized to detect surface-breaking cracks and corrosion in aircraft structures. Most military aircraft structures are made of 7000 series aluminum alloys (with 7075/7050/7085 being most common). The parts are primed and painted to provide protection from corrosion. Removal of paint schemes or corrosion is often performed through mechanically abrasive processes such as sanding, grinding, or machining, which smear small amounts of material over fine cracks and corrosion, making them less detectable with the penetrant inspection method. Chemical etching is used throughout the NDI industry as a method to remove approximately 0.0002 in. (0.00508 mm) of smeared metal prior to penetrant inspections [Refs 1 & 2]. The etching process typically requires multiple steps, which include precleaning the area, applying an etchant, applying a neutralizer, and applying a desmutting agent [Refs 1–3]. The etchant, neutralizer, and desmutting agents are typically acidic or alkaline and pose some safety hazards, as well as hazards to the aircraft when used in the field. The low-viscosity chemicals (similar to water) are prone to spilling and migrating into crevices in the structures (faying surfaces and fastener holes) near the inspection zone.

This SBIR topic seeks to develop paste forms of viable etchant materials with viscosities similar to toothpaste (70,000 to 100,000 cP) to reduce the hazards of using these chemicals during inspections of parts while they are still installed in the aircraft.

Various chemicals are currently used for these tasks and may be suitable for viscosity tailoring. The most common chemical mixtures used by NAVAIR are:

- Etchant: 0.705 oz (20 g) sodium hydroxide in 3.38 oz (100 ml) water
- De-smutting agent: 1.69 oz (50 ml) nitric acid added to 1.69 oz (50 ml) water
- Neutralizer: 0.353 oz (10mg) sodium bicarbonate in 3.38 oz (100 ml) water

Alternate combinations of chemicals, or other nonchemical processes that can evenly remove 0.0002 in. (0.00508 mm) of aluminum without smearing, are viable alternate approaches.

Etchant, neutralizer, and de-smut materials should have:

- Viscosity of 70,000 to 100,000 cP
- Shelf life of 6 months minimum (single-use needs for areas up to 16 in.<sup>2</sup> (40.64cm<sup>2</sup>))
- Useable temperature range of 50F (10C) to 120F (49C)
- Etch rates of 0.00002–0.0001 in. (0.00508–0.00254 mm)/min (removes 0.0002 in. (0.00508 mm) in 2–10 min)
- Etch rate should be uniform
- Chemicals should not require the user to mix components.

PHASE I: Develop, design, and demonstrate feasibility of etchant, neutralizer, and de-smut materials as described in the Description.

Phase I should include laboratory measurements of the viscosities of the chemicals and tests to demonstrate etch rates. Etch rates and uniformity of etching should be substantiated by laboratory testing and microscopy.



## VERSION 8

If a nonchemical approach is proposed, Phase I tasking should focus on demonstrating the proper etch rates and uniformity requirements are achieved. If the process poses safety hazards or other potential hazards to the aircraft, those hazards should be assessed and mitigated. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Phase II should focus on refining the proposed solution, demonstrating minimum shelf-life requirements, and optimizing packaging/storage concepts for single-use needs for areas up to 16 in.<sup>2</sup> (40.64 cm<sup>2</sup>).

PHASE III DUAL USE APPLICATIONS: Verify, validate, and finalize the prototype. Transition to applicable naval platforms and depots.

Pre-penetrant etch is required before penetrant inspection processes when any mechanical working (sanding, grinding, blasting, machining, etc.) of the part's metal surface during manufacturing or reworking is done. Penetrant inspections cannot be performed on painted parts, so mechanical paint stripping in-service parts requires etching before penetrant inspection can be performed. Penetrant nondestructive testing (NDT) is commonly used in a multitude of industries including infrastructure (buildings/bridges), transportation (auto/rail/ship), energy (oil and gas/hydrodynamic/wind), and space (rockets/payloads). Users of the penetrant NDT process could benefit from a safer etching process.

### REFERENCES:

1. Center for Nondestructive Evaluation. (n.d.). Material smear and its removal. Iowa State University. Retrieved July 1, 2021, from <https://www.nde-ed.org/NDETechniques/PenetrantTest/MethodsTech/materialsmear.xhtml>.
2. Moore, P. O., & Moore, D. G. (2016). Nondestructive testing handbook: Liquid penetrant testing (Vol. 1). American Society for Nondestructive Testing. [https://www.worldcat.org/title/nondestructive-testing-handbook-volume-1-liquid-penetrant-testing/oclc/1039286877&referer=brief\\_results](https://www.worldcat.org/title/nondestructive-testing-handbook-volume-1-liquid-penetrant-testing/oclc/1039286877&referer=brief_results).
3. Rainone, B., & Statham, A. (2011, October). Pre-penetrant etch. NADCAP NDIT Non-Destructive Testing Newsletter. <https://cdn.p-r-i.org/wp-content/uploads/2012/09/11094218/P111548NDTNewsletter.pdf>.

KEYWORDS: Penetrant; etchant; metal; smear; nondestructive; non-destructive

## VERSION 8

N221-014 TITLE: Synthetic Aperture Radar High Resolution Imaging when Performing Random Nonrepeating Radar Orbits

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR); Networked C3

TECHNOLOGY AREA(S): Air Platforms; Battlespace Environments; Information Systems

OBJECTIVE: Develop innovative Synthetic Aperture Radar (SAR) image formation/detections techniques for aerial vehicles performing Coherent Change Detection (CCD) that permits randomized radar orbits.

DESCRIPTION: Modern synthetic aperture radar signal processing algorithms retrieve accurate and subtle information regarding a scene that is being interrogated by an airborne radar. An important application of “continuous-stare” SAR systems involves detecting changes in an imaged scene. Current CCD radar techniques require flying the same orbit path repeatedly in order to look for changes in the scene. While this is acceptable in a benign threat environment, this predictable flight profile will be lethal to the air vehicle in a high-threat environment.

Achieving the alignment necessary between images (especially for CCD) is often difficult due to many factors beyond the control of the platform and sensor, including imaging geometry issues, air vehicle motion, errors in motion compensation, difficult clutter environments, clutter motion, and meteorological issues. Even when good alignment is obtained, weaker stationary target signature may be overcome by the surrounding clutter or masked by false alarms, requiring more sophisticated alignment algorithms and change metrics to extract the relevant image change information. Also, the steep depression angles required for urban imagery aggravate the effects of mismatched imaging geometry on change detection. These effects can be considerable, especially for CCD. Noncoherent change detection (NCCD) is often difficult in urban areas, for example, because large cultural object scatterers and their side lobes may be difficult to align (especially when imaging geometries are different) and may overwhelm weaker stationary target signatures. High-frequency CCD is potentially capable of detecting extremely subtle terrain disturbances, but is even more sensitive to alignment issues, typically producing an overwhelming number of naturally occurring false alarms, even in relatively benign cases. Inability to perform change detection (CD) may result in missed opportunities for extraction of significant information.

This SBIR topic seeks to develop and demonstrate techniques and transforms enabling CCD to be conducted with orbits that are randomized and nonrepeating. These techniques and transforms will be applicable to any aerial vehicle that is conducting SAR CCD missions under degraded conditions and various deployment environments. These techniques and transforms will be able to compare the coherent and/or noncoherent reference and test SAR images: (a) to detect image changes in randomized CCD radar orbits; (b) to extract automatic features such as stationary-vehicle Doppler “smears” embedded in urban clutter and other alternative change detection metrics; (c) sensitivity to various image formation techniques, including wavefront reconstruction (WR) and the polar format algorithm (PFA); and (d) sensitivity to phase history processing and conditioning methods.

Developed algorithms, techniques, transforms, and a simulation tool to estimate the SAR performance producing high-resolution radar imagery of stationary objects being performed by various aerial vehicles performing randomized CCD radar orbits will be tested during one, or possibly two, Government Rapid Prototype Experimentation Demonstration (RPED).

The offeror’s proposal must clearly explain how an aerial vehicle flight path variation SAR imagery collection will be accounted for with respect to:

## VERSION 8

1. Spatial registration of the reference SAR image with respect to the test SAR image using the available air vehicle platform motion data (e.g., Global Positioning System (GPS), Inertial Measurement Unit (IMU), etc.).
2. Spatially varying motion compensation (on points on ground plane and elevation) in a three-dimensional spatial domain using GPS denied navigation filtering software and simulation to assess SAR randomized and nonrepeating orbits imagery quality when the GPS is available or denied.
3. Spectral registration of both the test SAR image and the georegistered reference SAR image to extract the common Doppler data in the two images using the available air vehicle platform motion data.
4. Blind calibration of variations of the Image Point Responses (IPR) of the resultant (spatially and spectrally registered) reference and test SAR images using applicable adaptive filtering methods.

Air vehicles equipped with multichannel along-track monopulse/displaced phase center antenna-SAR (ATM-SAR) and high-Pulse Repetition Frequency AzScan-SAR Doppler Beam Sharpening-SAR (DBS-SAR) may be included in but are not required to be part of this SBIR topic.

Air vehicles performing Ground Moving Target Indicator (GMTI) using SAR imagery are not to be considered and are not part of this topic.

PHASE I: Develop and demonstrate techniques and transforms that exploit fundamental mathematical and physical properties of SAR signals to detect changes in imagery of a scene that are acquired via randomized CCD radar orbits of a SAR aerial platform using a single channel radio frequency (RF) sensor. Develop and provide techniques and transforms to retrieve the common spatial spectral information in randomized and nonrepeating orbits SAR imagery for coherent and noncoherent change detection (NCD). Develop and provide signal models for the effects of measured randomized and nonrepeating orbits SAR data calibration errors as related to radar electronics phase errors, and unknown motion errors. Deliver an analytical study of the randomized and nonrepeating orbits SAR signal, and identify its information contents in the spatial and spectral domains. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Further study, develop, and improve analytical principles developed in Phase I. Validate and mature the mathematical modeling and processing trade-analysis using an Integrated Fly-out Simulation (IFS) testbed to exploit randomized and nonrepeating orbits SAR imagery. Demonstrate, with minimal additional data processing in the image formation process, in a relevant flight environment the developed signal processing techniques and transforms that exploit randomized and nonrepeating single-channel SAR data acquired at different time points for high-resolution imagery of stationary objects during a Government sponsored RPED. Furthermore, real-time simultaneous imaging, as well as CCD/NCD, are to be demonstrated while the SAR data is being collected over a full aperture (slow-time).

PHASE III DUAL USE APPLICATIONS: Further research and development will be directed toward refining final Synthetic Aperture Radar (SAR) image formation/detections techniques. Incorporate these techniques based on results from tests conducted during Phase II.

Deploy Synthetic Aperture Radar Image (SAR) formation/detections techniques, in relevant environment aerial test environments, to validate techniques. Document lessons learned (what worked, what did not, areas of improvement). Identify gaps in SAR image formation/detections techniques and propose a solution to the identified gap to the Government working groups.

The completion of this phase would result in a mature capability, which would undergo an appropriate operational demonstration, such as surveillance and reconnaissance. These SAR image formation/detections techniques should prove the ability to provide high-resolution imagery of stationary objects by various aerial vehicles performing randomized CCD radar orbits.

## VERSION 8

Continue relationships with radar manufacturers with the objective of placing these Synthetic Aperture Radar Image (SAR) formation/detections techniques in major defense and commercial radars.

From a military application, these Synthetic Aperture Radar I (SAR) image formation/detections techniques would enable hypersonic air vehicles to have high-speed radar target detection, identification, and discrimination capability of stationary objects. From a commercial application, homeland security and commercial applications include guidance and control for robotic systems used in hazardous environments, and materials handling applications involving cranes; and loading equipment, and industrial equipment used in assembly, welding, inspection, and other similar operations. These algorithms could be used to support commercial ground mapping applications and current radar system performance for border patrol, drug traffic monitoring, perimeter surveillance, and air traffic control applications.

### REFERENCES:

1. Ranney, K. I., & Soumekh, M. (2005). Signal subspace change detection in averaged multilook SAR imagery. *IEEE Transactions on Geoscience and Remote Sensing*, 44(1), 201-213. <https://doi.org/10.1109/TGRS.2005.859956>.
2. Ranney, K., & Soumekh, M. (2005, May). Adaptive change detection in coherent and noncoherent SAR imagery. In *IEEE International Radar Conference, 2005*. (pp. 195-200). IEEE. <https://doi.org/10.1109/RADAR.2005.1435818>.
3. Burns, B., Clark, W., Alexander, J., Soumekh, M., Dorff G., Plaskyc, B., & Moussally, G. (2008, June). Change detection with delta-heading dual-pass UWB wide-beamwidth airborne SAR. *Proceedings of Tri-Service Radar Symposium*. <https://www.mssconferences.org>.
4. Himed, B., & Soumekh, M. (2006). Synthetic aperture radar–moving target indicator processing of multi-channel airborne radar measurement data. *IEE Proceedings-Radar, Sonar and Navigation*, 153(6), 532-543. <https://doi.org/10.1049/ip-rsn:20050128>.
5. Melvin, W. L., Wicks, M. C., & Brown, R. D. (1996, May). Assessment of multichannel airborne radar measurements for analysis and design of space-time processing architectures and algorithms. In *Proceedings of the 1996 IEEE National Radar Conference* (pp. 130-135). IEEE. <https://doi.org/10.1109/NRC.1996.510669>.
6. Melvin, W. L., & Wicks, M. C. (1997, May). Improving practical space-time adaptive radar. In *Proceedings of the 1997 IEEE National Radar Conference* (pp. 48-53). IEEE. <https://doi.org/10.1109/NRC.1997.588124>.
7. Himed, B., Salama, Y., & Michels, J. H. (2000, May). Improved detection of close proximity targets using two-step NHD. In *Record of the IEEE 2000 International Radar Conference [Cat. No. 00CH37037]* (pp. 781-786). IEEE. <https://doi.org/10.1109/RADAR.2000.851934>.
8. Soumekh, M. (1999). *Synthetic aperture radar signal processing with matlab algorithms* (Vol. 7). New York: Wiley. [https://www.worldcat.org/title/synthetic-aperture-radar-signal-processing-with-matlab-algorithms/oclc/39458891&referer=brief\\_results](https://www.worldcat.org/title/synthetic-aperture-radar-signal-processing-with-matlab-algorithms/oclc/39458891&referer=brief_results).
9. Melvin, W. L. (1996). RL-TM-96-5: Sample Selection for Covariance Estimation in Practical Airborne Environments. Rome Lab Rome NY. <https://apps.dtic.mil/sti/pdfs/ADA316361.pdf>.
10. Sanyal, P. K., Melvin, W. L., & Wicks, M. C. (1997, June). SENSIAC-SENS-TSRS-1997-25: Space-time adaptive processing for advanced airborne surveillance (AAS) bistatic radar (U). *Proceedings of the 43rd Annual Tri-Service Radar Symposium, 1997* (Vol. 1). <https://www.mssconferences.org>.
11. Melvin, W. L. (2002, September 16–17). ADP014046: Application of STAP in advanced sensor systems [Conference paper]. RTO SET Lecture Series, Istanbul, Turkey. <https://apps.dtic.mil/sti/citations/ADP014046>.
12. Himed, B., & Soumekh, M. (2005, December). AFRL-SN-RS-TR-2005-388: Synthetic Aperture Radar-Moving Target Indication (SAR-MTI) Processing of Multi-Channel Airborne Radar Measurement (MCARM) Data. Rome Lab Rome NY. <https://apps.dtic.mil/sti/citations/ADA443155>.

## **VERSION 8**

13. Melvin, W. L., Callahan, M. J., & Wicks, M. C. (2002, April). Bistatic STAP: application to airborne radar. In Proceedings of the 2002 IEEE Radar Conference (IEEE Cat. No. 02CH37322) (pp. 1-7). IEEE. <https://doi.org/10.1109/NRC.2002.999683>.

KEYWORDS: Radar; SAR; imagery; detection; orbit; target

## VERSION 8

N221-015      TITLE: Electromagnetic Interactions Between Cables, Antennas, and Their Environments

OUSD (R&E) MODERNIZATION PRIORITY: Networked C3

TECHNOLOGY AREA(S): Electronics

OBJECTIVE: Develop a multifidelity simulation tool for analyzing electromagnetic interactions between cables, antennas, and their environments for Navy aircraft.

DESCRIPTION: Modern Navy aircraft are replete with cable harnesses that carry sensitive information and provide power to avionics, weapons, sensors, control surfaces, and landing gear. The internal arrangement and layout of cable bundles in aircraft is a critical part of the design of new and existing platforms. Rules of thumb for cable harness separation, shielding, and layout exist, but they often result in over-engineering the solution and are not always effective.

A need exists for a multifidelity cable harness tool that can be used during all phases of an aircraft's life cycle to assess potential for self-interference, as well as disruption due to external sources such as EMP, HIRF, and lightning. NAVAIR analysts often need to provide rapid feedback regarding a design trade study or changes to a piece of avionics and its associated cables on an existing aircraft. As aircraft designs mature and more information about the structure of the platform, avionics, and cable harnesses becomes available, analysts want to work in the same tool leveraging the investment made in the previous analyses, all the way through to the simulation of the full aircraft for certification purposes.

The design process needs to consider cross-talk between cables within a harness or between cables in different harnesses. It must also include coupling to and from antennas located on the aircraft. There must be consideration for the electromagnetic compatibility of systems connected to the power bus, which becomes complicated as the number of systems on the same bus increases. Finally, a cable harness design should account for the impact of coupling from the external electromagnetic environment, including Electromagnetic Pulse (EMP), High Intensity Radiated Fields (HIRF) and lightning. All these interactions must be considered for cable harnesses in aircraft to understand the impact on the devices attached to the cables.

Multifidelity analysis tools exist that predict electromagnetic interference (EMI) between RF systems where the dominant coupling path is from a transmitting antenna to a receiving antenna. Such tools are extremely powerful for NAVAIR analysts because the same software tool can be used for quick, as well as rigorous analyses, and the models developed for a platform can be maintained throughout the lifecycle of that platform. However, a similar multifidelity solution for the cable harness analysis problem does not exist in a single software package. There are existing spreadsheet-based approaches for analyzing power buses. There are existing high-fidelity, full-wave solvers for analyzing the various modes of aircraft cable harness coupling. However, there are several limitations with existing approaches and tools. Spreadsheet-based solutions do not scale well with problem size, they are prone to errors, and make configuration control a challenge. Hybrid solvers, that include full-wave simulations of structures with transmission line modeling of cable harnesses, work well when all the necessary details are available to the analyst and there is enough time to build up the complex models of the platform with all the details of the various cable harnesses. However, this level of detail is usually not available until the design of the aircraft is almost complete. Medium-fidelity cable harness simulation tools based on modified transmission line theory are available. However, there is not a common platform to allow the medium-fidelity simulations to evolve as the design changes, and eventually incorporate the aircraft structure in a hybrid simulation. The compatibility problem must be set up for each environment individually, and they have, thus far, not been automated to consider multiple self-interference and external environments automatically.

## VERSION 8

PHASE I: Demonstrate solutions for low-, medium-, and high-fidelity approaches to the cable harness analysis problem considering both self-interference and external interference scenarios, such as those addressed in MIL-STD-461 and 464. Review approaches with NAVAIR technical staff to ensure that they fit the current and future workflow for NAVAIR programs. Develop a detailed software architecture plan for Phase II implementation that includes a user-friendly graphical user interface (GUI) and configuration control that allows for sharing of projects between groups working on different problems for the same platform (e.g., cross talk analysis, power bus analysis, and external field analyses). The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and demonstrate a robust, multifidelity software solution that allows NAVAIR analysts to consider very simple problems when there is limited information, all the way through full aircraft models with all the geometric, material, and cable harness details. Provide interfaces for reading common CAD formats. Demonstrate the accuracy, robustness, and speed of the tool. Develop a Phase III commercialization plan.

PHASE III DUAL USE APPLICATIONS: Complete development, and perform final testing and validation of a commercial grade application.

The tool is suitable for electromagnetic compatibility evaluation of any civilian or military electronic system, including within the commercial aviation and automobile industries.

### REFERENCES:

1. German, F., Annamalai, K., Young, M., & Miller, M. C. (2010, July). Simulation and data management for cosite interference prediction. In 2010 IEEE International Symposium on Electromagnetic Compatibility (pp. 869-874). IEEE.  
<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5711394>.
2. Baum, C. E., Liu, T. K., & Tesche, F. M. (1978, November). On the analysis of general multiconductor transmission-line networks. Interaction Note, 350(6), 467-547. <http://ece-research.unm.edu/summa/notes/In/0350.pdf>.
3. Plumer, J. A. (1980). Protection of aircraft avionics from lightning indirect effects. In AGARD Atmospheric Elec.-Aircraft Interaction 26 p (SEE N80-31743 22-33).  
<https://apps.dtic.mil/sti/pdfs/ADA087976.pdf#page=131>.

KEYWORDS: Cable harness; cross talk; lightning; Electromagnetic Pulse; EMP; electronic vulnerability; electromagnetic interference

## VERSION 8

N221-016 TITLE: Autonomous Onboard Processing Hostile Fire Sensor System

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR);Microelectronics

TECHNOLOGY AREA(S): Electronics;Materials / Processes;Weapons

OBJECTIVE: Develop and deliver chip-scale multifunction midwave infrared (MWIR) metasurface optics sensor system for detecting and geolocating hostile fire to be mounted on, or installed within, small battery operated Group 1 unmanned air vehicles (UAV) and self-guiding target munitions.

DESCRIPTION: Especially when first engaged, it is often difficult for a soldier, UAV operator, or autonomous self-guiding target munitions to quickly ascertain from where hostile fire has originated. This confusion prevents a quick geolocation and effective auto target coordinates handoff to counter and eliminate hostile fire.

Traditional uncooled microbolometer technologies for small arms bullet detection do not have the potential performance on small battery operated Group 1 UAVs and self-guiding target munitions mainly due to the bullet's large thermal time constants. Fast detector response times are required to detect fast moving objects at peak energy.

This SBIR topic seeks to improve upon the detection and geolocation capabilities of standard broadband optics sensors such as uncooled microbolometer heat detectors by distinguishing between a hostile fire signal and self-emitting blackbody radiation.

To this end, a chip-scale multifunction MWIR metasurface optics hostile fire sensor system for hostile fire detection and geolocation is needed. Demonstrate a thorough understanding of the computational targeting cue algorithms embedded with optics models that minimize calibration and computational processing of spectra needed to make the chip-scale multifunction MWIR metasurface optics hostile fire sensor system successful. As part of the effort, a sensor system design concept should be developed using available existing chip-scale optical components.

Because this topic sensor system is meant to be carried/installed on battery operated Group 1 UAVs (e.g., UVision Hero-20, Teledyne FLIR R80D SkyRaider) and self-guiding target munitions, it must be extremely light weight, low power, and possess an appropriate form factor: this is of primary importance in not degrading other Group 1 UAV and self-guiding target munitions' performance. Additionally, it should be compatible and not interfere with other sensing systems such as acoustic, electro-optical and infrared sensors.

The sensor system need not be imaging, but must provide at least angular direction to the origin of the hostile fire event. In order to provide the user with the best chance of quickly identifying and engaging the threat, the sensor system should minimally be capable of identifying the angle to the threat with  $< 30^\circ$  resolution and  $< \pm 15^\circ$  error, but ideally  $< 5^\circ$  resolution with  $< \pm 2.5^\circ$  error. This must be balanced against Size, Weight, Power, and Cost (SWAP-C); horizontal angular (azimuth) resolution is more important than vertical (zenith).

The time lag between the shot and geolocating origin data to the user/or other UAV/self-guiding target munitions system components should be minimal, ideally  $< 50$  ms. Of course, probability of detection at tactically relevant ranges for small arms (500–600 m), such as common assault rifles and carbines, and medium arms (1–1.5 km), such as large rifles and machine guns, should be maximized ( $> 90\%$  minimum, ideally  $> 95\%$ ) and false alarms close to zero. Other features, such as weapons identification, the ability to



## VERSION 8

snuff alerts generated from friendly fire, and range to target, are desirable. The system must minimally operate within the entire UAV and self-guiding target munitions flight/performance envelope.

Appropriate algorithms to be incorporated into the design are to provide, at a minimum: (a) angular direction to the origin of hostile fire event in all-weather day/night conditions; (b) a least probability of detection versus range; (c) angular resolution and error; (d) time to detect; (e) geo-location; and (f) sources of false alarms and potential mediation.

Testing during later stages of development must include valuation of brass board system using live fire and controlled motion studies over a wide range of relevant background environments.

**PHASE I:** Demonstrate the feasibility of a complete chip-scale multifunction MWIR metasurface optics hostile fire sensor system design using only components which are commercial off-the-shelf (COTS) or those that could reasonably be designed and fabricated within the time and budget constraints. The sensor design need not be optimized for SWAP-C at this stage, but it must show extensibility to small battery operated UAVs and self-guiding target munitions systems. A complete and thorough understanding of the algorithms necessary to make the sensor system successful must be demonstrated. Rigorous modeling should be performed to estimate sensor system performance, including at least probability of detection versus range, angular resolution and error, time to detect, geolocation, and any other features. Sources of false alarms and potential mediation should be well thought out and incorporated into the design. The Phase I effort will include prototype plans to be developed under Phase II.

**PHASE II:** Using the results of Phase I, fabricate and deliver a prototype chip scale multifunction MWIR metasurface optics hostile fire sensor system. Prototype should minimally meet requirements for a minimum of TRL 4: component and/or breadboard validation operating in a laboratory environment. All required sensors must be carried or installed small battery operated UAVs, but processing and power may be external at this stage, so long as a detailed design path is provided to show that it can all be integrated into the small battery operated UAVs and self-guiding target munitions (full integration is preferred). Probability of detection, angular resolution and error, and time to detect shall be measured through live-fire testing at close-to-moderate distance, at least 50–1000 m. False alarm mitigation techniques should also be laboratory or field tested when possible.

Perform data collection for the purposes of evaluating sensor and system performance at appropriate program intervals, to include live fire testing. Cameras and sensors must be appropriately calibrated and characterized including sensor pose. Live fire testing shall occur at relevant system ranges and locations relative to system or sensor. Testing during later stages of development must include valuation of brass board system using live fire and controlled motion studies over a wide range of relevant background environments.

Algorithms must minimally include detection, tracking, spatiotemporal registration, motion stabilization. Algorithms shall be capable of running in real time in SWAP-C appropriate hardware as in a postprocessing mode (e.g., on a desktop computer for analysis and precollected data).

**PHASE III DUAL USE APPLICATIONS:** Transition applicable techniques and processes to a production environment with the support of an industry partner. Finalize a sensor design with appropriate SWAP-C and form factor based on human factors testing. Determine the best integration path as a capability upgrade to existing or future systems, including firmware and interfaces required to meet sensor interoperability protocols for integration into candidate systems as identified by the Navy.

From a military application, this system gives small battery operated UAVs and self-guiding target munitions the capability to provide accurate azimuth, elevation, and range information about hostile fire

## VERSION 8

shot line as well as the geolocation of the hostile fire origin to blue forces and if equipped encounter and eliminate hostile fire sources.

From the commercial application, this systems capability will be able to detect smoke and fire at speeds comparable to or faster than conventional detection systems. This makes them a good choice in settings like laboratories, chemical plants, refineries, and boiler rooms where it is critical to detect smallest temperature changes or hidden pockets of embers at an early stage.

### REFERENCES:

1. Tidhar, G. (2013). Hostile fire detection using dual-band optics. SPIE Newsroom. <https://www.spie.org/news/4851-hostile-fire-detection-using-dual-band-optics?SSO=1>.
2. Li, X., Greenberg, J. A., & Gehm, M. E. (2019). Single-shot multispectral imaging through a thin scatterer. *Optica*, 6(7), 864-871. <https://www.osapublishing.org/optica/fulltext.cfm?uri=optica-6-7-864&id=415033>.
3. Stancic, I., Bugarcic, M., & Perkovic, T. (2017). Active IR system for projectile detection and tracking. *Advances in Electrical and Computer Engineering*, 217(4) 125–130. <https://doi.org/10.4316/AECE.2017.04015>.
4. Dereniak, E. L., & Boreman, G. D. (1996, April). *Infrared Detectors and Systems*. Wiley & Sons. NY, USA. ISBN: 978-0-0471-12209-8. [https://www.worldcat.org/title/infrared-detectors-and-systems/oclc/1023904718&referer=brief\\_results](https://www.worldcat.org/title/infrared-detectors-and-systems/oclc/1023904718&referer=brief_results).
5. Blake, T. A., Kelly, J. F., Gallagher, N. B., Gassman, P. L., & Johnson, T. J. (2009). Passive standoff detection of RDX residues on metal surfaces via infrared hyperspectral imaging. *Analytical and bioanalytical chemistry*, 395(2), 337-348. <https://doi.org/10.1007/s00216-009-2907-5>.
6. Pauli, M., Seisler, W., Price, J., Williams, A., Maraviglia, C., Evans, R., Moroz, S., Ertem, M. C., Heidhausen, E., & Burchick, D. A. (2004). Infrared detection and geolocation of gunfire and ordnance events from ground and air platforms. Naval Research Lab Washington DC Tactical Electronic Warfare Division. <https://apps.dtic.mil/sti/pdfs/ADA460225.pdf>.
7. Snarski, S., Menozzi, A., Sherrill, T., Volpe, C., & Wille, M. (2010, May). Results of field testing with the FightSight infrared-based projectile tracking and weapon-fire characterization technology. In *Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security and Homeland Defense IX* (Vol. 7666, p. 76662C). International Society for Optics and Photonics. <https://www.spiedigitallibrary.org/conference-proceedings-of-spie/7666/76662C/Results-of-field-testing-with-the-FightSight-infrared-based-projectile/10.1117/12.850523.full>.
8. Department of Defense. (2013, September 16). *Defense Acquisition Guidebook* (pp. 848–849). Department of Defense. <https://at.dod.mil/sites/default/files/documents/DefenseAcquisitionGuidebook.pdf>.

KEYWORDS: Hostile Fire; chip-scale; metasurface; unmanned air vehicle; UAV; optics; munitions

## VERSION 8

N221-017 TITLE: Manned-Unmanned Teaming Survival in an Adaptive World

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML);Autonomy;General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Battlespace Environments;Electronics;Information Systems

OBJECTIVE: Develop and demonstrate an innovative, mission effective Unmanned Air Vehicle (UAV) capability to assist manned-unmanned teaming (MUM-T) to challenge and/or negate radars and radar networks by enabling UAVs to automatically sense and communicate weaknesses in a radar and/or radar networks.

DESCRIPTION: Current airborne electronic warfare (EW) systems must first identify a threat radar to determine the appropriate preprogrammed electronic countermeasure (ECM) technique. This approach loses effectiveness as radars evolve from fixed analog systems to programmable digital variants with unknown behaviors and agile waveforms. Future radars will likely present an even greater challenge as they will be capable of sensing the environment and adapting transmissions and signal processing to maximize performance and mitigate interference effects.

A growing concept in the field of MUM-T is the idea of using a team of cooperating unmanned and manned air vehicles to significantly challenge and/or negate existing and/or new, unknown, and adaptive radar networks in real time. Some MUM-T strategies to challenge radar networks may include using either jamming techniques, deception techniques, or a combination of the two, to assist in completing MUM-T mission objectives. A UAV may be tasked to engage a radar or radar network using noise jamming to mask its radar return or that of another vehicle. Similarly, a UAV may be assigned to deceive a radar by directing a delayed signal toward the victim radar, which has the effect of producing a radar phantom perceived by the radar as an object at a false range and/or bearing. Depending on the number of UAVs in the MUM-T and the number of radars in the radar network, the UAVs may be able to employ different strategies simultaneously.

A characteristic of these MUM-T strategies is that they require the UAVs to follow time-critical, directionally dependent trajectories with tight constraints in order to be successful, from the start of the defensive task to the very end. It is absolutely necessary that UAVs are able to control their own movements during defensive tasks, as well as navigate in a coordinated fashion enroute to the subsequent tasking. A valid configuration for a UAV is a position in the three-dimensional space environment, which is collision free. At any given trajectory, the algorithm generates a random node and, subsequently, inspects the trajectory path from the generated node to closest previously expanded node for collisions. If collisions exist along the trajectory path, the generated node is discarded and a new random node is generated; otherwise, the generated node is added to the set of expanded nodes. The goal state is reached and ultimately a collision-free path from start to goal state in the three-dimensional environment. UAVs participating in MUM-T missions will need to have local analysis and action capabilities, as well as the ability to speak with and update each other.

The successful completion of this SBIR effort will culminate in demonstrations of the MUM-T challenge and/or negate capabilities being able to:

- Isolate unknown radar signals in the presence of other hostile, friendly, and neutral signals.
- Deduce the threat posed by a radar and/or a radar network.
- Synthesize and transmit signals to achieve a desired effect on the radar and/or a radar network.
- Assess the effectiveness of strategies based on radar and radar network behaviors.

## VERSION 8

Simulation-based demonstrations of the effectiveness of small UAV sensor suites in performing various challenging and/or negating missions will help planners and decision makers determine the appropriate mix of UAVs and sensors that will be required to support MUM-T missions, and will show performance as a function of system cost. The flexibility of distributing the sensors across several Group 1-5 UAV platforms enables customized sensor suite solutions that both meet various mission needs and minimize cost. Therefore, a MUM-T member will not have to pay for sensing capabilities that they do not want or require.

This SBIR topic seeks to develop a MUM-T challenging and/or negating product(s), which includes the following features and functions:

- High-Level Decision Maker—adaptive allocation to each payload manager
- Director—multifunction optimization and conflict resolution
- Multiobjective Optimization and Learning Engine—dynamic, context-based learning
- Weight Adjuster—autonomously adapt to multiple UAV trajectories
- Compliant interfaces—seamless connection to external subsystems
- Multiobjective reasoning in dynamically changing environments
- Context-based consideration of long-term benefits and tradeoffs in effect option set selection
- Efficient resource allocations
- Reinforcement learning framework that overcomes uncertainty and avoids reliance on static models
- Adaptation across multiple timescales to accommodate dynamic contested environment
- Robust to different environments through contextual processing
- Integration with nonstandard platforms via translation with platform agnostic reasoning
- Vendor-agnostic integration with various Group 1-5 UAV platforms and their respective systems and subsystems
- Hybrid decentralized approach for local decisions to support multiplatform collaboration
- Near real-time mission feedback with reduced processing times
- Lightweight signaling in a hierarchical command and control (C2) structure supporting battlefield applications with multiple distributed platforms
- Negating radio frequency (RF), cyber takeover of unmanned air vehicles

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor 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: Research, develop, and propose a design concept with the potential of realizing the goals in the Description above. Describe and quantify how the proposed solution offers enhancement(s) over current technology approaches and/or how it augments other strategies/technologies. Conduct necessary investigation and simulation on the design and performance of the components to demonstrate the feasibility and practicality of the proposed system design, minimizing user input. Identify any technical challenges that may cause a performance parameter(s) not to be met, results of any modeling, safety issues, and estimated costs. The Phase I effort will include prototype plans to be developed under Phase II.

## VERSION 8

PHASE II: Develop, optimize, demonstrate, and deliver the technology identified in Phase I. The technology derived designs will then be modified as necessary to produce final prototypes. Work with the Government team to test the algorithms against data collected from candidate sensors relevant to the Navy with Government furnished MUM-T air vehicles. The prototypes must be capable of demonstrating the performance goals stated in the Description above in a rapid prototype experiment demonstration (RPED) environment. Phase II will include MUM-T field testing against a radar of interest with at least 10 UAVs and one manned aircraft to validate performance claims. Document the design specifications, performance characterization, and any recommendations for future development.

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

PHASE III DUAL USE APPLICATIONS: Incorporate the lessons learned from Phase II into the detailed design. Further, refine detailed design to address any unique requirements and to improve performance robustness and capability for manned-unmanned team operational scenarios. Develop preproduction and production components and subsystems for integration into manned and unmanned air and ground vehicles. Further miniaturization and low-cost manufacturability of the capability may be required. Develop relevant environment test methods and evaluate the final designed system performance in field or at sea demonstrations.

Integrate the technology using engineering model of proposed product/platform or software, along with full report of development, capabilities, and measurements (showing specific improvement metrics).

Military Application: Integration of the products and resulting capabilities with current and future manned and unmanned aircraft teams will enhance team survivability during electronic warfare engagements against layered defense systems.

Commercial Application: Potential low-cost development program for unmanned systems to autonomously, interoperate with other unmanned and manned systems in uncontrolled, unsupervised, underwater, ground, and airspace environments or operations safely, e.g., package delivery and photography.

### REFERENCES:

1. Pachter, M., Chandler, P. R., Purvis, K. B., Waun, S. D., & Larson, R. A. (2004). Multiple radar phantom tracks from cooperating vehicles using range-delay deception. In *Theory and Algorithms for Cooperative Systems* (pp. 367-390). <https://doi.org/10.1142/9789812796592>.
2. Vakin, S. A., Shustov, L. N., & Dunwell, R. H. (2001). *Fundamentals of electronic warfare*. Artech. [https://www.worldhistory.biz/download567/FundamentalsOfElectronicWarfare\\_worldhistory.biz.pdf](https://www.worldhistory.biz/download567/FundamentalsOfElectronicWarfare_worldhistory.biz.pdf).
3. Dubins, L. E. (1957). On curves of minimal length with a constraint on average curvature, and with prescribed initial and terminal positions and tangents. *American Journal of Mathematics*, 79(3), 497-516. <https://doi.org/10.2307/2372560>.
4. Dennis Jr, J. E., & Schnabel, R. B. (1996). *Numerical methods for unconstrained optimization and nonlinear equations*. Society for Industrial and Applied Mathematics. [https://books.google.com/books?hl=en&lr=&id=ksvJTtJCx9cC&oi=fnd&pg=PR1&ots=BKjNEK9Jxx&sig=D\\_WgyKYkpZY8Xv\\_mEs4qGe-RSbA#v=onepage&q&f=false](https://books.google.com/books?hl=en&lr=&id=ksvJTtJCx9cC&oi=fnd&pg=PR1&ots=BKjNEK9Jxx&sig=D_WgyKYkpZY8Xv_mEs4qGe-RSbA#v=onepage&q&f=false).
5. Grabbe, M. T., & Hamschin, B. M. (2013). Geo-location using direction finding angles. *John Hopkins APL Technical Digest*, 31(3), 254-262. <https://www.jhuapl.edu/Content/techdigest/pdf/V31-N03/31-03-Grabbe.pdf>.
6. Hughes, E. (2018, October). Detecting drones with Doppler-based radar. *Aerospace & Defense Technology*. Retrieved June 28, 2021, from <https://www.aerodefensetech.com/component/content/article/adt/features/articles/33023>.

## VERSION 8

7. de Quevedo, Á. D., Urzaiz, F. I., Menoyo, J. G., & López, A. A. (2019). Drone detection and rcs measurements with ubiquitous radar. Information Processing and Telecommunications Center. Universidad Politécnica de Madrid, Madrid, Spain, 2019.  
[https://radar2018.org/abstracts/pdf/abstract\\_74.pdf](https://radar2018.org/abstracts/pdf/abstract_74.pdf).
8. Department of Defense. (2006, February 28). DoD 5220.22-M National Industrial Security Program Operating Manual (Incorporating Change 2, May 18, 2016). Department of Defense.  
<https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>.

KEYWORDS: Unmanned Air Vehicle; UAV; Manned-Unmanned Team; MUM T; electronic warfare; EW; reinforcement learning; simulation; radar

## VERSION 8

N221-018 TITLE: Smart Avionics Systems Environment for Automatic Test Systems

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML)

TECHNOLOGY AREA(S): Information Systems

OBJECTIVE: Identify, characterize, and standardize the use of smart avionics systems' data-driven capabilities. Leverage Units Under Test (UUTs) health, environment, and performance data collection capabilities of these systems. Develop innovative technologies to streamline adoption of condition-based and predictive maintenance techniques in Test Program Sets (TPSs).

DESCRIPTION: Naval aviation maintenance is shifting course from reactive maintenance (after component failure) and is preparing to adopt new maintenance strategies that rely upon Condition-Based Maintenance (CBM) and Prognostics and Health Management (PHM) techniques. Recently, new technologies have allowed for avionics systems to collect "Smart" data related to system health, performance, and environmental factors. This will allow for advanced automated analyses to better diagnose avionics systems, and even help predict failures, and provide preventative maintenance actions before the system actually fails. These maintenance strategies require monitoring, managing, and predicting the condition of avionics systems to enable informed action by maintenance staff. Efficient diagnostics and repairs serve to avoid disruptions in flight operations due to equipment downtime.

The primary impacts of the implementation of the proposed technology would be reduced cost of avionics maintenance and increased availability of aircraft platforms. Transitioning to CBM/PHM strategies requires the integration and application of smart avionics systems health, environment, and performance data into the naval enterprise sustainment operations, spanning Automated Logistics Environment (ALE), Automatic Test Equipment (ATE), and TPS usage. Characterizing the data collection capability of smart aircraft systems (components with embedded computer systems to collect and interpret system data) will facilitate this integration and application, but no standard format currently exists for the compilation of all available data.

Further technology development must enable the use of such a standardized data set to inform diagnostics and repair of avionics modules and components. Current maintenance methodologies (as defined in the Naval Aviation Maintenance Program COMNAVAIRFORINST 4790.2 [Ref 4]) and environments do not provide the flexibility and interoperability to implement new techniques and industry standards for characterizing design-time and run-time data specification and information exchange. Therefore, in order to address these shortfalls, the Navy is seeking innovative technologies and application development methodologies through this topic.

The advanced technologies and techniques implementing the smart avionics systems environment should be based on open standards and support both legacy and new naval aviation weapon systems and Automatic Test Systems (ATS). In addition, through the use of open system standards that have been developed and are currently being developed, the resulting environment and tools should be more easily transported to the electronics maintenance environments of other Military Services.

PHASE I: Demonstrate the feasibility of developing innovative software technologies, methodologies, and tools for health, environment, and performance data sharing between weapon system UUTs and ATS systems to enable improvements in weapon system availability, and advance the application of smart systems capabilities and open standards. Develop a plan for integrating the advanced technologies, tools, and methodologies required to achieve the stated objective. The Phase I effort will include prototype plans to be developed under Phase II.

## VERSION 8

PHASE II: Build and integrate a prototype environment to validate the technology and characterization methodology. Work with Navy to produce, test, and demonstrate a new capability that satisfies the objectives of this topic.

PHASE III DUAL USE APPLICATIONS: Build, certify, and deploy a production toolset at a Navy organization. Commercialize the resulting technology.

There is significant potential for commercialization of the technology. For example, the technology can be applied in other Defense and commercial industries where failures in critical assets have a great economic or safety impact (e.g., automotive, aviation, or power). Similar to naval aviation, the health, environment, and performance data for the assets in these other areas are being integrated and are moving more toward CBM and PHM concepts.

### REFERENCES:

1. Office of the Under Secretary of Defense for Acquisition and Sustainment. (2020, August 14). DoD Instruction 4151.22 Condition-based maintenance plus for materiel maintenance. Department of Defense. <https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/415122p.pdf?ver=2020-08-14-152511-117>.
2. Automatic Test Systems Executive Directorate. (2017). DOD Automatic Test Systems Master Plan 2017. Department of Defense. [https://www.acq.osd.mil/log/mpp/ATS/.ats\\_library.html/2017\\_DoD\\_ATS\\_Master\\_Plan.pdf](https://www.acq.osd.mil/log/mpp/ATS/.ats_library.html/2017_DoD_ATS_Master_Plan.pdf).
3. Prognostics and Health Management Working Group. (2017, December 13). IEEE Std 1856™-2017: IEEE Standard Framework for Prognostics and Health Management of Electronic Systems. IEEE. <https://doi.org/10.1109/IEEESTD.2017.8227036>.
4. NAVAIR. (2021, February 01). Naval Aviation Maintenance Program COMNAVAIRFORINST 4790.2D. <https://www.navair.navy.mil/Naval-Aviation-Maintenance-Program>.

KEYWORDS: Automatic Test Equipment; Condition-Based Maintenance; Prognostics; Avionics Maintenance; Health Management; Diagnostics



## VERSION 8

N221-019 TITLE: Long-Range Passive Surveillance in Anti-Access/Area-Denial Environments

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 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 passive surveillance techniques that utilize the wideband signal processing and direction of arrival measurement capabilities of modern signals intelligence/electronic intelligence (SIGINT/ELINT) systems to act as a passive radar system leveraging opportunistic emitters in the operational area to develop and maintain the tactical surface picture in Anti-Access/Area-Denial (A2/AD) environments.

**DESCRIPTION:** Operations in high-threat environments drive both our own forces, as well as our adversaries, to effectively go dark by limiting detectable emissions. In such situations, long-range situational awareness provided by radar and SIGINT/ELINT systems is lost. However, in most of these environments, particularly those in littoral regions, many other electromagnetic emissions are present from other sources, including commercial ships, land-based emitters, and even satellites. In principle, an airborne platform's mission radar could use these emissions to maintain situational awareness by processing the reflections of these emissions from surrounding ships. However, this requires that not only the opportunistic emission is in the operating band of the mission radar (typically x-band), but also be suitable for the particular radar function (detection/tracking or imaging). This requirement is highly restrictive. On the other hand, modern SIGINT/ELINT collection systems operate over a very wide-frequency range and have wide-instantaneous bandwidth processing capabilities, making them an excellent passive radar system in A2/AD environments where opportunistic emissions may be the only means to develop and maintain a long-range surface picture. The nature of the available emissions should be considered and their suitability for use in vessel detection, tracking, and inverse synthetic aperture imaging over frequency ranges typical of modern SIGINT/ELINT 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) formerly Defense Security Service (DSS). The selected contractor 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 passive radar concepts suitable for opportunistic emission exploitation by conceptual modern airborne SIGINT/ELINT systems. Supporting analyses should include the presence of potential opportunistic emissions in littoral and blue water oceanic regions. Hypothetical coverage maps should be

## VERSION 8

developed for operations in peace time, heightened tensions, and during conflicts. The concepts should consider the relatively modest antenna gain (0-3 dBi) of typical SIGINT/ELINT systems. The feasibility of coherent signal processing approaches of these opportunistic emissions should be considered. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Based on Phase I results, candidate concept(s) will be matured through more detailed high-fidelity analyses with a focus on a particular SIGINT/ELINT system identified by the Navy sponsor. Examine integration concepts. Working with the Navy sponsor, assess software and possible firmware impacts to accommodate the candidate techniques. Identify critical technical challenges and perform necessary analysis and as required experimentation to understand the associated risk. The Phase II deliverable should provide a detailed conceptual approach with supporting analyses of sufficient detail to support follow-on design and integration in the candidate airborne platform system. A prototype system should be developed and demonstrated to assess feasibility of the proposed approach.

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

PHASE III DUAL USE APPLICATIONS: Complete development, perform final testing, integrate, and transition the final solution to naval airborne SIGINT/ELINT systems.

The technology can support a variety of passive RF surveillance system for air surveillance, facility monitoring, or coastal navigation.

### REFERENCES:

1. Pavlikov, V. V., Volosyuk, V. K., & Zhyla, S. S. (2018, July). Ultra-wideband passive radars fundamental theory and applications. In 2018 IEEE 17th International Conference on Mathematical Methods in Electromagnetic Theory (MMET) (pp. 1-6). IEEE.  
<https://doi.org/10.1109/MMET.2018.8460251>.
2. Matthes, D. (2005, May). Convergence of ESM sensors and passive covert radar. In IEEE International Radar Conference, 2005. (pp. 430-44). IEEE.  
<https://doi.org/10.1109/RADAR.2005.1435863>.
3. Clark, B., & Gunzinger, M. (2015). Winning the airwaves: Regaining America's dominance in the electromagnetic spectrum. Center for Strategic and Budgetary Assessments.  
[https://csbaonline.org/uploads/documents/CSBA6292-EW\\_Reprint\\_WEB.pdf](https://csbaonline.org/uploads/documents/CSBA6292-EW_Reprint_WEB.pdf).
4. Department of Defense. (2006, February 28). DoD 5220.22-M National Industrial Security Program Operating Manual (Incorporating Change 2, May 18, 2016). Department of Defense.  
<https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>.

KEYWORDS: Passive radar; anti access/area denial; A2/AD; signal processing; parasitic radar; wideband

## VERSION 8

N221-020 TITLE: Heat Tolerant Decoy Towline for Towed Decoy

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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

OBJECTIVE: Develop an advanced heat tolerant towline for towed decoy with an operating temperature limit of at least 700 °C with a goal operating temperature limit of 1000 °C.

DESCRIPTION: The current Navy towed decoy deployment system location places the trailing towline in a position where hot engine exhaust encroaches on it during high Angle of Attack (AOA) maneuvers that use engine afterburners. The hot engine exhaust encroachment causes material failure of the towline that can cause towline separation or prevent operation of the decoy. A towline typically contains from two to five high-voltage wires and a single-mode optical fiber. Zylon fibers provide towline tensile strength in excess of 200 lb (90.72 kg). The towline diameter is restricted by available spool volume to about 0.062 in. (1.57 mm), and a bend radius of approximately 0.25 in. (6.35 mm) is required to meet unspooling functionality. The towline must remain flexible over a storage temperature range between -60 °C to +85 °C. The current decoy insulated wire consists of the polyimide EKJ (DuPont) that is tape-wrapped around a fine-gauge conductor. Studies and material analysis have shown that the EKJ insulation tends to electrically break down on exposure to temperatures above 550 °C for more than 30 seconds (s) at the high voltages (> 2,500 V) necessary to properly energize the decoy electronics. The electrical breakdown of the insulation leads to arcing and current leakage between conductors, which causes the decoy power supply to shut down due to overcurrent. The Zylon fibers that provide tensile strength also fail rapidly above 650 °C, resulting in parting of the towline and loss of the decoy. Ideally, as a near-term goal, a towline operating temperature of 700 °C for six towline exposures of > 30 s each is sought, and as a longer term goal, an operating temperature as high as 1000 °C with the same or greater exposure times is desired. This can possibly be achieved by perfecting the existing science in the towline systems, and/or devising novel towline systems, e.g., the conducting and strength members may ultimately be a single entity. Such advanced tow cables may also require materials that are not entirely organic in nature as they will most likely not survive extreme conditions up to 1000 °C. In this regard, innovative research involving inorganic/ceramic and other hybrid material systems may be useful and such innovative ideas are sought in this SBIR topic.

PHASE I: Demonstrate the feasibility of an advanced heat tolerant tow cable concept, including addressing in detail how each component of the proposed tow cable will meet the material and structural demand with regard to the sought requirements. Preliminary component level testing results supporting the design, i.e., proof-of-concept results are highly desirable although not a must. Propose Phase II cable fabrication and test effort that will fully demonstrate the sought requirements. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype tow cable. Perform component level testing supporting the design to demonstrate the sought parameters of both near-term and long-term goals. Fabricate and test multiple lengths, i.e., from 10–100 ft (3.05–30.48 m) of tow cables.

PHASE III DUAL USE APPLICATIONS: Once an effective, affordable, and improved temperature towed decoy cable design has been demonstrated, the Navy can reflect the new capability in performance specifications. The Navy and the small business can negotiate to provide that improved performance to the Navy.

Improved high temperature cables would be useful for commercial aircraft wiring around hot engines and for cables for sensors in deep earth drilling operations.

## VERSION 8

### REFERENCES:

1. Kolel-Veetil, M. K., & Keller, T. M. (2007). Polymeric protection of Navy fighter jet towlines. Naval Research Laboratory. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a516758.pdf>.
2. Texas A&M. (n. d.). Materials for extreme environments. Engineering Magazine. Retrieved March 16, 2021, from <https://engineeringmagazine.tamu.edu/materials-for-extreme-environments/>.
3. The Grainger College of Engineering. (n. d.). Mechanical properties and materials for extreme conditions. University of Illinois Urbana-Champaign. Retrieved March 16, 2021, from <https://matse.illinois.edu/research/mechanical-properties-and-materials-extreme-conditions>.
4. Glenn Research Center. (n. d.). Materials & structures for extreme environments. NASA. Retrieved March 16, 2021, from <https://www1.grc.nasa.gov/research-and-engineering/materials-structures-extreme-environments/>.
5. Reference added 01/12/2022 – Towline Cable Design - [https://navysbir.com/n22\\_1/N221-020\\_Reference\\_5\\_Towline\\_Cable\\_Design.pdf](https://navysbir.com/n22_1/N221-020_Reference_5_Towline_Cable_Design.pdf)

KEYWORDS: Towline; high temperature; HT; HT wire insulation; HT fibers with tensile strength; decoy; HT fibers

## VERSION 8

N221-021      TITLE: Modeling and Process Planning Tool for Hybrid Metal Additive/Subtractive Manufacturing to Control Residual Stress and Reduce Distortion

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a modeling and process planning tool for hybrid metal additive manufacturing processes to predict and minimize the residual stress and distortion of a part.

DESCRIPTION: Additive Manufacturing (AM) technologies have become increasingly important for the rapid production of industrial products. However, AM processes also pose challenges with associated features such as residual stress. Many AM process parameters and post-processes may affect the final residual stress of the part. Laser scanning patterns during AM processing can significantly affect distortion and residual stress distribution in an AM process [Ref 1]. Residual stress caused by the thermal cycles in AM processing is a critical issue for the fabricated metal parts since the steep residual stress gradients generate part distortion which dramatically deteriorates the functionality of the end-use parts. Thus, the residual stress can degrade the AM part's quality, service life, precision, and fatigue performance. For example, after AM processing, a considerable amount of chip curl out of the cutting plane was observed, which was not observed when cutting wrought parts of the same material. This out-of-plane curl was attributed to the residual stress distribution in the part from an AM process, and indicated that residual stresses from the AM process can impact chip formation during machining [Ref 2].

Hybrid additive/subtractive manufacturing is a process that combines both AM and subtractive manufacturing, such as machining, to create parts with high complexity, tight tolerances, and good surface finish. The hybrid process integrates the AM capability of fabricating almost any complex geometry and the machining capability of offering high part quality and short processing times. Properly chosen tooling and cutting conditions may induce stresses along the outer surface to counteract those imposed from the preceding AM process [Ref 3]. Thus, if well planned, a hybrid process can potentially be used to produce a part with controlled stresses and minimum distortion.

Due to the complexity of the residual stresses, some researchers have investigated the modeling of dual processes or hybrid processes. For example, finite element modeling was used to predict the residual stresses developed during heat treatment processes and the distortion during machining operations [Ref 4]. Another finite element method, utilizing the level set method to define the cutting tool path, was able to predict results such as residual stresses and part distortion [Ref 5]. The results show that machining can partially eliminate the residual stresses and distortion caused by laser cladding. However, the entire part needs to be modelled to predict residual stress, making the analysis computationally very expensive. The challenge increases when using a modeling tool to plan and benchmark between different tool paths and deposition strategies. Thus, an efficient and effective modeling and planning tool for AM processes is needed.

The Navy requires a modeling and process planning system for a hybrid metal additive manufacturing process. The tool will integrate the effects of additive and subtractive processes. These results will be the basis for hybrid process planning in order to control the residual stress and minimize the distortion of the resulting parts. This modeling and planning system should also be computationally efficient.

PHASE I: Demonstrate the feasibility of a modeling and planning tool to predict the residual stress and distortion of an AM part based on key hybrid process parameters for both the additive and subtractive steps. This tool should be capable of predicting the residual stress in a Ti-6Al-4 coupon, which is repaired

## VERSION 8

using a hybrid process. This coupon should be developed independently. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a full-scale modeling and process planning tool prototype to efficiently predict the residual stress and distortion of hybrid additive/subtractive parts based on various process parameters, including, but not limited to, energy density, build orientation, build tool path, material properties, scan speed, layer thickness, part geometry, machining conditions, sequence between additive (conventional AM, cold spray, and welding) and subtractive processes, and post processing (stress relieving, normalization, etc.). Compare the predicted residual stress of the test cases by printing and machining Ti-6Al-4V samples to show the effectiveness of the model's prediction capability and the computational efficiency of the planning capability. Demonstrate the solution(s) in a real-world AM processing scenario and its possible transition into both military and commercial applications. Note: No Government test facility should be needed.

PHASE III DUAL USE APPLICATIONS: Validate and demonstrate an aircraft ready AM part using a hybrid process. This part should conform to all design tolerances and strength requirements predicted by the physics-based modeling solution created in Phase II.

Metal AM component studies are being conducted in both the private and public sector for parts that might benefit from a hybrid additive/subtractive construction using AM. AM components can reduce weight, tooling costs, and material waste. By understanding the distortions and internal stresses of as-built and post-processed parts, a manufacturer can reduce material waste and time required to redesign components to meet requirements.

### REFERENCES:

1. Ren, K., Chew, Y., Fuh, J. Y. H., Zhang, Y. F., & Bi, G. J. (2019). Thermo-mechanical analyses for optimized path planning in laser aided additive manufacturing processes. *Materials & Design*, 162, 80-93. <https://doi.org/10.1016/j.matdes.2018.11.014>.
2. Lane, B. M., Moylan, S. P., & Whinton, E. P. (2015, April). Post-process machining of additive manufactured stainless steel. In *Proceedings of the 2015 ASPE Spring Topical Meeting: Achieving Precision Tolerances in Additive Manufacturing* (pp. 27-29). [https://www.researchgate.net/profile/Brandon-Lane-2/publication/280598788\\_Post-Process\\_Machining\\_of\\_Additive\\_Manufactured\\_Stainless\\_Steel/links/55bcd59908ae092e96638084/Post-Process-Machining-of-Additive-Manufactured-Stainless-Steel.pdf](https://www.researchgate.net/profile/Brandon-Lane-2/publication/280598788_Post-Process_Machining_of_Additive_Manufactured_Stainless_Steel/links/55bcd59908ae092e96638084/Post-Process-Machining-of-Additive-Manufactured-Stainless-Steel.pdf).
3. Heigel, J. C., Phan, T. Q., Fox, J. C., & Gnaupel-Herold, T. H. (2018). Experimental investigation of residual stress and its impact on machining in hybrid additive/subtractive manufacturing. *Procedia Manufacturing*, 26, 929-940. <https://doi.org/10.1016/j.promfg.2018.07.120>.
4. Ma, K., Goetz, R., & Srivatsa, S. K. (2010). Modeling of residual stress and machining distortion in aerospace components (preprint). Air Force Research Lab Wright-Patterson AFB OH Materials and Manufacturing Directorate. <https://apps.dtic.mil/sti/pdfs/ADA523921.pdf>.
5. Salonitis, K., D'Alvise, L., Schoinochoritis, B., & Chantzis, D. (2016). Additive manufacturing and post-processing simulation: laser cladding followed by high speed machining. *The International Journal of Advanced Manufacturing Technology*, 85(9), 2401-2411. <https://doi.org/10.1007/s00170-015-7989-y>.

KEYWORDS: Additive Manufacturing; Design; Distortion; Hybrid Process; Residual Stress; Subtractive Manufacturing

## VERSION 8

N221-022 TITLE: Compact Thermal Energy Storage

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR);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 the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a compact thermal energy storage device.

**DESCRIPTION:** The latest version of the Department of Defense's Anti-Radiation Homing Missile (AARGM-ER) must store the thermal energy generated by its electronics on board during its mission. The current energy storage device concept utilizes wax in an aluminum container. This concept consumes a lot of space within the guidance section and the control section of the missile. The current Thermal Protection System in the Guidance Section requires 267 in.<sup>3</sup> (4350 cm<sup>3</sup>) and in the Control Section requires 119 in.<sup>3</sup> (1950 cm<sup>3</sup>). The Navy requires that the space consumed by these devices be reduced by no less than one half. These devices are configured to surround the electronics packages and may require an asymmetric shape. Prior to captive carry the device will be at 71°C due to potential worst case storage condition and experience a temperature rise up to 76°C. The devices together must be able to absorb a constant 156 Btu/min while maintaining an electronic package's temperature at no more than 85 °C, with an initial starting temperature of 76 °C (captive carry end temperature). Thermal absorption performance will be evaluated for durations of 5, 15, and 30 minutes. The devices must be reusable and rapidly regenerated within 1 hour after absorbing energy during captive carriage of the missile with temperature conditions decreasing from 76°C to 71°C. The combined weight of the devices cannot exceed 21.75 lb. (9.86 kg). Further the device shall provide secondary structure to support approximately 4-5 Circuit Card Assemblies (CCA) with associated cabling. It is desired that the devices require no consumables, and do not require preventative maintenance. The Navy is looking for a unique and innovative approach to reduce the size of the current energy storage device in the guidance and control sections while maintaining the identified temperature and weight parameters. Analysis and/or modeling are approaches that may be used to validate the ability of this unique/innovative approach to achieve the size reduction while maintaining the temperature and weight parameters.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor 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.

## VERSION 8

PHASE I: Develop, design, and demonstrate the feasibility, through analysis and/or modeling, of a device to absorb the required thermal energy within the required size. For additional information please refer to MIL-STD-810 for fighter aircraft environments. The Phase I effort will include prototype plans to be developed under Phase II.

**PHASE II:** Design, test and demonstrate a device that will work within a missile guidance and control type structure, environment, and mission profile.

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

PHASE III DUAL USE APPLICATIONS: Design and demonstrate a device that will work within a missile guidance and control type structure, environment, mission profile and different asymmetric designs while adapting and accommodating different electronic packages. Transition the technology to applicable naval platforms.

The technology could be used within any electronic enclosure exposed or generating high temperatures to reduce its thermal footprint.

### REFERENCES:

1. Greene, E. E. (2013, July 29). Thermal protection and control [Internship Final Report, University of Nebraska-Lincoln]. <https://ntrs.nasa.gov/api/citations/20140002341/downloads/20140002341.pdf>.
2. Marongiu, M. (2019, March 6). Thermal management of electronic equipment using phase change materials (PCMs). Electronics COOLING. <https://www.electronics-cooling.com/2019/03/thermal-management-of-electronic-equipment-using-phase-change-materials-pcms/>.
3. Wang, Y., Gao, X., Chen, P., Huang, Z., Xu, T., Fang, Y., & Zhang, Z. (2016, March). Preparation and thermal performance of paraffin/Nano-SiO<sub>2</sub> nanocomposite for passive thermal protection of electronic devices, 96, 699-707. <https://doi.org/10.1016/j.applthermaleng.2015.11.106>.

KEYWORDS: Thermal management; Reduced Footprint; No preventative maintenance; Missile; Thermal Energy; Thermal Protection



## VERSION 8

N221-023 TITLE: Miniaturized Sonobuoy High-Data-Rate Tether

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 innovative miniaturized data tether deployment modules for use in a variety of sonobuoys for antisubmarine warfare (ASW).

DESCRIPTION: NATO A-size buoys have been produced in large quantities over many decades. The standardization of the A-size bare buoy form factor has supported a tremendous economy of scale to reduce unit production costs and has driven designs of compatible platform launchers and stores management, as well as logistics support. The advent of new sonobuoys requiring improved sensors requires miniaturization of components in the sonobuoys to allow for more space for sensor arrays. Additionally, deep and long-life sonobuoys have unique size and capacity constraints due to additional tether length and/or larger power supplies. With advances in miniaturization technologies, the Navy seeks new and innovative data tether deployment modules for use in multiple sonobuoys.

This SBIR topic addresses the need for new data tether modules to provide a strengthened, full-duplex communications datalink between the surface unit and the suspended payload. Following air launch and water entry, the data tether deploys the payload to a programmed depth and then suspends the payload for the duration of operations. The data tether module functionality includes: (a) the upper and lower mechanical, data, and power interfaces with the sonobuoy surface and payload units; (b) tether deployment; (c) full-duplex communications; (d) suspension of payload unit static and dynamic loads while providing for requisite acoustic isolation; and (e) packaging as an extractable sonobuoy module. Power for any interface electronics would come from either or both the surface and payload units.

The performance objectives address two miniaturized data tether deployment modules.

Module #1 Performance Objectives:

- deployed tether length threshold: a fixed, to-be-specified length ranging from 1,000 ft–12,000 ft (304.8 m–3,687.6 m); objective: command selectable with up to four to-be-specified lengths ranging from 1,000 ft–16,000 ft (304.8- m–4,876.8 m)
- static tensile load threshold: 5 lb (2.27 kg); objective: 10 lb (4.54 kg)
- full-duplex data rate threshold: up to 100 kb/s; objective: up to 1.5 Gb/s
- diameter: threshold < 4.5 in. (11.43 cm)
- cylindrical stack height: threshold 8 in. (20.32 cm); objective 6 in. (15.24 cm)
- power consumption threshold: < 1.5 W; objective: < 0.5 W
- operational life threshold: 14 days; objective 180 days
- ability to be ruggedized and packaged to withstand the shock, vibration, pressure, temperature, humidity, electrical power conditions, etc., encountered in a system built for long-term, nonclimate- controlled storage, and for airborne use

## VERSION 8

- reliably deployed in sea-state conditions 0 through 5 (international scale) with 90% two-dimensional current profile meantime between equipment failure threshold: 90 days; objective: 180 days
- full-rate production cost: threshold < \$1,000; objective < \$500 (based on 1000 units)

### Module #2 Performance Objectives:

- deployed tether length threshold: a fixed, to-be-specified length ranging from 90 ft–1,500 ft (27.43 m–457.2 m); objective: command selectable with up to four to-be-specified lengths ranging from 90 ft–1,500 ft (27.43 m–457.2 m)
- static tensile load threshold: 4 lb (1.81 kg); objective: 8 lb (3.63 kg)
- full-duplex data rate threshold: up to 100 kb/s; objective: up to 1.5 Gb/s
- diameter: threshold < 3.5 in. (8.89 cm); objective: < 4.5 in. (11.43 cm)
- cylindrical stack height: threshold < 2 in. (5.08 cm); objective < 1.5 in. (3.81 cm)
- power consumption threshold: < 1.5 W; objective: < 0.5 W
- operational life threshold: 6 hr; objective 8 hr
- ability to be ruggedized and packaged to withstand the shock, vibration, pressure, temperature, humidity, electrical power conditions, etc., encountered in a system built for long-term nonclimate- controlled storage, and for airborne use
- reliably deployed in sea-state conditions 0 through 5 (international scale) with 90% two-dimensional current profile meantime between equipment failure threshold: 4 hr; objective: 8 hr
- full-rate production cost: threshold < \$500; objective < \$250 (based on 1,000 units)

Technology Innovation will include a sonobuoy high-data-rate tether deployment module that meets the performance objects and metrics below. Currently, there does not exist a small diameter fiber optic tether capable of supporting a deep sonobuoy deployment. Fiber optics have reduced volume per foot compared to existing sonobuoy tethers that will enable the development of a deep sonobuoy high-data-rate deployment module. In addition, fiber optics support a significantly higher data rate from the deep sensor to the surface. Successful sonobuoy high-data-tether deployment module development will result in a deep sonobuoy capability. Specific technology innovation is a small high-data-rate fiber deployment module with a high-strength member supporting deep depth. Details of this innovation include, but are not limited to:

1. High strength tether that is > 3 mi long and has the ability to support the weight of sensors at the bottom of the tether for up to six months.
2. High-strength tether diameter must be small enough to fit into the fiber-optic deployment module with a size of 4.5 in. (11.43 cm) in diameter and 6 in. (15.24 cm) in height. This further complicates the ability of the tether meeting the high strength necessary for a deep-deployed sonobuoy.
3. The tether needs to double as the communication link from depth to the surface. The use of fiber optics as the tether results in transmission of acoustic detection using a high-digital-data rate from depth to the surface that is required by this topic. Copper wire is not capable of providing the high-data rates required.
4. Module #2 requires a much smaller high-data-rate fiber-optic deployment module. This is due to the limited space in future tactical sonobuoys as a result of increased sensor space requirements, and for use in miniature sonobuoys (mBuoy). Miniature sonobuoys provide aircraft the capability to carry twice as many sonobuoys. Module #2 has the same innovations and challenges described in 1-3 above, but with a greatly reduced depth. The remaining innovations ? (a) small module, (b) high strength tether, and (c) small-diameter fiber optic ? are the same as above.

PHASE I: Develop, design, and demonstrate the feasibility of a viable and robust miniaturized data tether deployment module solutions consisting of a tether deployment canister packaged with the requisite length of tether and interface electronics, as required to pass uplink and downlink communications, to

## VERSION 8

receive power from the upper and lower sonobuoy components, and with a compliant suspension, to isolate a notional acoustic payload from surface dynamics. 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 under Phase II.

PHASE II: Design, fabricate, and deliver miniaturized data tether deployment module prototypes based on the design from Phase I. Test and fully characterize the system prototype. The interface electronics to the sonobuoy upper and lower units need not meet the miniature packaging requirements to allow use of discrete assemblies, in anticipation of tight integration of these interfaces with the sonobuoy's upper and lower units during Phase III.

PHASE III DUAL USE APPLICATIONS: Integrate the technologies into a logistically supportable sonobuoy package that is compatible with air carriage and air drop for existing and future Navy launch platforms.

The small size, low cost, and standardized form factor of mBuoys will expand market potential enabling new applications and greater use of sensors for ocean and climate research, marine mammal surveys, economic exclusion zone monitoring, and customs and border protection.

### REFERENCES:

1. Holler, R. A., Horbach, A. W., & McEachern, J. F. (2008). The ears of air ASW: a history of US Navy sonobuoys. Navmar Applied Sciences Corporation. Warminster, PA, 2008. <https://www.worldcat.org/title/ears-of-air-asw-a-history-of-us-navy-sonobuoys/oclc/720627294>.
2. Military Analysis Network. (1998, December 12). AN/SSQ-53 directional frequency analysis and recording sonobuoy. Federation of American Scientists. <https://www.fas.org/man/dod-101/sys/ship/weaps/an-ssq-53.htm>.
3. Military Analysis Network. (2000, April 23). AN/SSQ-62B/C/D/e directional command activated sonobuoy system (DICASS) Sonobuoy. Federation of American Scientists. <https://fas.org/man/dod-101/sys/ship/weaps/an-ssq-62.htm>.

KEYWORDS: Miniaturized; Tether; Sensors; Antisubmarine Warfare; ASW; Acoustics; Airborne

## VERSION 8

N221-024 TITLE: Automated Air Traffic Control Communication Technology Enhancement

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML);Autonomy;General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Provide an intelligent, realistic, and autonomous communications software tool intended to provide relevant radio and chat information exchanges within training systems and feedback to improve the fidelity and quality of communication-based training.

DESCRIPTION: The current Air Traffic Control (ATC) operational environment requires an operator to listen and filter through a large number of communications (voice and/or text) in order to complete their objectives. During training, the quality of the “non-target” communications, or “noise” is lacking, or does not exist, due to technological or instructor workload limitations. Calls that are replayed on a loop can alert the student to the normal pattern and allow them to pick out the target communications more easily than they would in an operational environment. This limitation decreases the training fidelity of the environment and can cause a lack of trainee skill.

This SBIR topic seeks to provide a software solution for enhancing communications-based training systems for the ATC community and others through development of a capability to deliver intelligent, autonomous, and realistic background calls and text chat (i.e., not scripted) to increase training fidelity. This communication-based training solution must allow students to interact with relevant entities (e.g., aircraft, personnel within tower, personnel of adjacent airspace towers, command and control agencies) via voice and text, and be provided responses (for target communication responses, as well as nontarget). The system should also provide diagnostic feedback to the student after the exercise—specifically targeted at whether or not the student is communicating with the correct entities or “target” communications—and whether or not the content of their messages is appropriate for the situation. Instructors must be able to modify the environment of the scenarios, to include certain amounts and types of aircraft (and other calls) in order to simulate different mission sets, and difficulty levels.

As part of this SBIR effort, development and demonstration of hardware and/or software technology prototype is desired that provides this capability stated above. The hardware and software must meet the DoD system 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 2]. This solution should require minimal operator guidance to modify and maintain.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor 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 feasibility of an autonomous voice- and text-based communications capability to support signal-to-noise ratio in training scenarios. The early system should demonstrate an initial

## VERSION 8

autonomous capability to provide audio and text during training, with some type of performance feedback to users, such as text or graphics-based information on user performance. 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 sample training environment. The prototype capability should be able to provide realistic, autonomous voice- and text-based communications from various types of aircraft for the appropriate set of training scenarios, and provide feedback to students.

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

PHASE III DUAL USE APPLICATIONS: Obtain management framework certification for an authority to operate within operational/training systems. Finalize, refine, and integrate the solution within the training system environment. Transition the technology to a Naval Air Station via a Program Office. This solution can be used in the defense industry as a framework to provide higher fidelity settings for communications-based training.

Commercial industries that could benefit from this type of training system include commercial aviation and air traffic control, in similar ways to how the technology would benefit the listed platforms. Outside of air traffic control, 911 operators and first responder training could benefit from this type of communications-based training system. Any job that filters through a large amount of voice and text communications (e.g., 911 dispatcher) could be trained using such a solution.

### REFERENCES:

1. Department of Defense. (2020, December 29). DoDI 8510.01: Risk Management Framework (RMF) for DoD Information Technology (IT), Incorporating Change 3. Department of Defense. [https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/851001p.pdf?ver=qEE2HGN\\_HE4Blu7161t1TQ%3D%3D](https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/851001p.pdf?ver=qEE2HGN_HE4Blu7161t1TQ%3D%3D).
2. Department of Defense. (2019, October 7). DoDI 8500.01, Incorporating Change 1: Cybersecurity. Department of Defense. [https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/850001\\_2014.pdf](https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/850001_2014.pdf).
3. Defense Counterintelligence and Security Agency. (n.d.). <https://www.dcsa.mil/>.
4. Department of Defense. (2006, February 28). DoD 5220.22-M National Industrial Security Program Operating Manual (Incorporating Change 2, May 18, 2016). Department of Defense. <https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>.
5. FREQUENTLY ASKED QUESTIONS [https://navysbir.com/n22\\_1/N221-024\\_FAQs.pdf](https://navysbir.com/n22_1/N221-024_FAQs.pdf)

KEYWORDS: Air Traffic Control; Training System; Communications-based Training; Training Fidelity; Diagnostic Feedback; Instructor Workload

## VERSION 8

N221-025 TITLE: DIGITAL ENGINEERING - Advanced Technologies for Automated Replay and Reconstruction of Theater Undersea Warfare Mission Data

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML)

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 the capability to automate multi-platform Theater Undersea Warfare (TUSW) mission data collection and use for time-periods of up to 180 days.

DESCRIPTION: Current processes and tools to reconstruct TUSW mission data information are manually cumbersome, labor-intensive, and time-consuming. The existing state-of-practice is to (a) bring together data recordings from different tactical systems across multiple platforms, and (b) filter and edit the data files to get some level of synchronization and fidelity across time and space. The resulting collated data set is used for replay to provide a wide-area Theater view of events. The TUSW mission is sufficiently complex and unique that there is no analogous commercial state of the art from which to draw.

The Navy desires a TUSW mission capability to be fielded within the AN/UYQ-100 Undersea Warfare Decision Support System (USW-DSS) to provide rapid data recording and replay, and event reconstruction through automation, which provides minimal user pre-processing. The rapid replay solution must use a robust automated data recording and automated replay, storage, archival, and retrieval procedure that is built into the overall system architecture, along with a logically formulated user methodology supported by reliable software toolsets.

To enable in-depth operational analysis and assessment by subject matter experts, the ability to comprehensively reconstruct long-term TUSW events is essential. Additionally, reconstruction is expected to support system engineers in improving the usability of the system from a human-factors perspective. These require the capability to (a) capture user interactions with the system (like menu selections, mouse clicks, etc.), and (b) collect Theater team member interactions (for example, between watchfloor personnel, command site and subordinate tactical units).

Since TUSW events can extend over several weeks and possibly months, the solution will collect mission data over a 180-day time-period and manage the data without burdensome Information Technology (IT) administration and intervention. It is often that high-interest events cross over from one Theater to another requiring the solution to have a multi-Theater system synchronization capability. The solution will be analyzed by the Government to ensure it effectively provides the rapid replay and comprehensive reconstruction required to conduct operational analysis and assessment, and perform usability improvements. Once the prospective contractor(s) demonstrates that their technology is beneficial on data they provide, the Navy will evaluate the solution with relevant tactical data to assess how well the capability meets performance goals, with an eye to the feasibility of having the capability meet Navy information assurance specifications for classification security. Once the technology is deemed acceptable

## VERSION 8

to integrate into USW-DSS, the capability will be integrated into a future USW-DSS build for metrics-based Independent Validation and Verification (IV&V) tests during the normal USW-DSS System Integration Test events to qualify and certify the updated USW-DSS system for Fleet use.

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

PHASE I: Develop a concept for automated replay and reconstruction of TUSW Mission Data over extended time-periods of up to 180 days. Demonstrate the concept meets the parameters in the Description. Establish feasibility in meeting Navy needs by sample testing, modeling, simulation, and analysis. The Phase I Option, if exercised, will include the initial design specifications and a capabilities description to build a prototype solution in Phase II. State of the practice standards such as Google Protocol Buffers (protobuf) and Advanced Message Queuing Protocol (AMQP) are to be supported. Cybersecurity is to be in accordance with Navy Authorizing Official (NAO) policies and procedures. This information will be provided during Phase I.

PHASE II: Based on the results of the research in Phase I, develop and deliver the prototype solution architecture, methodology and toolsets for incorporating automated replay and reconstruction into the USW-DSS. Demonstrate the prototype meets the required range of desired performance attributes given in the Description. System performance will be demonstrated through installation and prototype testing on a testbed with the lead system integrator.

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 as a software configuration item in the production USW-DSS. The performer will be expected to follow the Continuous Integration/Continuous Delivery (CI/CD) cycle as mandated by the Navy's DevSecOps processes and the transition Program Office (IWS 5). The Navy will conduct metrics-based Independent Validation and Verification (IV&V) tests during the normal USW-DSS System Integration Test events to qualify and certify the component for Fleet use.

Data replay and reconstruction are key components of engineering systems that support a variety of military applications involving aircraft and ground vehicles in tactical operations. Commercial applications where the technology could be used include the aircraft industry, land-based shipping operations, and maritime shipping, travel, and rescue operations.

### REFERENCES:

1. Pollock Jr, James and Cembrola, Joan. "Method for the collection and replay of submarine operational data". US Patent 6,016,453, awarded 18 January 2000.  
<https://patents.justia.com/patent/6016453>.
2. Aldinger, Tye and Kao, Jimmy. "Data Fusion and Theater undersea warfare – an oceanographer's perspective." IEEE Oceans '04 MTS/IEEE Techno-Ocean '04. 9-12 November 2004, Kobe, Japan.

## VERSION 8

<https://ieeexplore.ieee.org/abstract/document/1406451> (Locate a local library with a copy of these proceedings at <https://www.worldcat.org/title/oceans-04-mtsieee-techno-ocean04-bridges-across-the-oceans-conference-proceedings-november-9-12-2004-kobe-japan/oclc/1109187758#borrow>).

3. “AN/UYQ-100 Undersea Warfare Decision Support System (USW-DSS).” Navy Fact File, at <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166791/anuyq-100-undersea-warfare-decision-support-system-usw-dss/>.
4. Reference added 12/8/2021 – Undersea Warfare Decision Support System (USW DSS) Overview - [https://navysbir.com/n22\\_1/N221-025\\_Reference\\_4\\_USW\\_DSS\\_Overview.pdf](https://navysbir.com/n22_1/N221-025_Reference_4_USW_DSS_Overview.pdf)
5. Reference added 01/12/2022 – Software List – Distro A - [https://navysbir.com/n22\\_1/N221-025\\_Reference\\_5\\_Software\\_List\\_Distro\\_A.xlsx](https://navysbir.com/n22_1/N221-025_Reference_5_Software_List_Distro_A.xlsx)

KEYWORDS: Theater Undersea Warfare; TUSW; TUSW Mission Data; Automated data recording; Multi-Theater; Automated Replay; Event Reconstruction



## VERSION 8

N221-026 TITLE: DIGITAL ENGINEERING - Automated Network Cluster Generation

OUSD (R&E) MODERNIZATION PRIORITY: Networked C3

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 algorithm that automatically identifies clusters of nodes that should participate in specific information flows based on a combination of geographic location information type needs.

**DESCRIPTION:** Navy command and control networks currently implement “mass delivery”, meaning data from each node is sent to all nodes. This method of delivery makes sense given the networks’ initial purpose of providing a common track picture on each node. Having all sensor data available on each node allows each node to generate the same track picture as all other nodes. Future Navy requirements will add additional data to existing networks, using the Communications as a Service (CaaS) concept, and will require existing command and control networks be expanded to a larger number of nodes. At some network size, the concept of mass delivery will drive the network to its throughput limit for a given point-to-point communication. A concept to separate network size from throughput is to prioritize sending specific data to certain clusters of nodes that need that specific data. The data need can be characterized by a combination of geographic proximity and data type. Currently no known solutions exist that can accomplish this task. The Navy seeks an algorithm that automatically identifies clusters of nodes that will participate in specific information flows based on a combination of geographic location information type needs.

The solution should automatically assign network nodes to clusters. The cluster generator will be implemented in a high-level language (such as Python, MATLAB, and so forth) to facilitate its evaluation in simulation. Metrics available in the reference by J. Yang can be used to assess the quality of the clusters [Ref 1]. The default metric will be a comparison of the network size achievable using the clusters to the network size achievable using mass delivery, assuming a constant maximum throughput. The clusters may be generated upon the node entering the network or discovered during network execution. The net entry approach is intended to avoid chokepoints (i.e., communications that exceed the point-to-point throughput limit). The discovery method is an ad-hoc method and is intended to detect and mitigate chokepoints. Both methods will be simulated. Each approach optimizes the use of the network throughput. The solution(s) will be tested in a testbed provided by the Government. Based on the cluster definitions, the scheduling concept will be demonstrated in a simulation showing increased fidelity.

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

## VERSION 8

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

PHASE I: Develop a concept for an automated network cluster generator that automatically assigns network nodes to clusters. Demonstrate the concept meets the parameters of the Description. Show feasibility through analysis, modelling, simulation, and testing. The Phase I Option, if exercised, will include the initial design specifications and a capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver the prototype automated network cluster generator based on the results of Phase I. Demonstrate the prototype meets the required range of desired performance attributes given in the Description. System performance will be demonstrated through installation and prototype testing in a testbed. The scheduling concept, based on the cluster definitions, will be demonstrated in simulation with increased fidelity.

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. The automated clustering concept will be merged with existing command and control software to assist in generating the Time-Division Multiple Access (TDMA) transmit/receive schedule. Working prototype scheduling algorithms will be delivered to the Navy Program of Record for integration into the scheduling algorithm to be deployed. Assist the Government in integrating the suite of scheduling concepts that best support the requirements of the network capability to be deployed.

This technology will benefit the commercial industry for companies or universities that use large amounts of computers to control aspects or communications within their industry.

### REFERENCES:

1. J. Yang, J. McAuley and J. Leskovec, "Community Detection in Networks with Node Attributes," 2013 IEEE 13th International Conference on Data Mining, Dallas, TX, USA, 2013, pp. 1151-1156, doi: 10.1109/ICDM.2013.167. <https://ieeexplore.ieee.org/document/6729613>; <https://www-cs.stanford.edu/~jure/pubs/cesna-icdm13.pdf>.
2. Emmons S, Kobourov S, Gallant M, Börner K (2016) Analysis of Network Clustering Algorithms and Cluster Quality Metrics at Scale. PLoS ONE 11(7): e0159161. <https://doi.org/10.1371/journal.pone.0159161>; <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0159161>.

KEYWORDS: Large networks; clusters of nodes; cluster generator; optimized throughput; information flows; ad-hoc network.

## VERSION 8

N221-027            TITLE: DIGITAL ENGINEERING - Undersea Warfare Tactical Advantage Support Kit

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Information Systems

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

OBJECTIVE: Develop a capability that embeds prompts for system usage within the Anti-Submarine Warfare (ASW) system to support proficiency and mission success.

DESCRIPTION: The AN/SQQ-89A(V)15 Surface Ship Undersea Warfare system is used to conduct operations across the entire detect to engage spectrum, including active sonar, passive sonar, sonobuoy operations, and weapons targeting and firing. Mission success relies on operator proficiency during tactical operations.

ASW operations require a highly-perishable, complex skill set. While operator proficiency can be developed and maintained using training, the ultimate purpose of improved proficiency is effective use of the mission system during tactical operations. Providing individualized support in the midst of tactical operations will reduce the time to correctly perform the complex functions from target detection to target engagement, improving mission effectiveness.

The Navy seeks a technology that provide embedded individualized support as operators perform each ASW function. It should be able to extend across the range of support that might be needed, from the apprentice level to those who are masters of employment. The proposed technology will also extend to the full range of functions operators are required to perform. The Navy believes the technology associated with this SBIR topic will provide opportunities to implement artificial intelligence and machine learning (AI/ML) techniques.

The solution should demonstrate an improvement in operator performance for apprentice operators without degrading performance of journeyman and master operators, translating to latency reduction of 25% in end-to-end metrics relative to unassisted employment of the system. Testing of the solution will occur using the IWS 5.0 Advanced Capability Build (ACB) step testing process.

Initial testing of the proposed technology may be demonstrated at the contractor facility, but a more robust evaluation of a fully developed toolset will eventually be conducted using representative data gathered from a fleet test event, at a developer site such as the Lockheed Martin Anti-Submarine Warfare Laboratory in Manassas, VA, or from an appropriate Navy training facility such as Fleet Anti-Submarine Warfare Training Center San Diego, CA (FASW-TC). In order to properly evaluate the technology, the technology will be used with a range of sonar operators across the full functionality of the AN/SQQ-89A(V)15 tactical system. These interactions would include real-world or synthetic scenarios that span the detect-to-engage timeline. During Phase I we ask the offeror to propose a representative data set they

## VERSION 8

feel will demonstrate the unclassified capability. During Phase II, the Navy will provide classified data sets to fully exercise the toolset during the detect-to-engage timeline.

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

PHASE I: Develop a concept for a tactical advantage support kit (TASK) that provides individualized tactical support prompts across a range of proficiency levels and different tasks within a larger system of systems. Demonstrate the concept meets the parameters of the Description. Show feasibility through analysis, modelling, simulation, and testing. The Phase I Option, if exercised, will include the initial design specifications and a capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of the research in Phase I, develop and deliver the prototype solution with architecture and methodology for incorporating the TASK. Demonstrate the prototype meets the required range of desired performance attributes given in the Description. System performance will be demonstrated through installation and prototype testing on a testbed with the lead system integrator.

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 as an embedded capability within a future build of AN/SQQ-89A(V)15. Support the Navy in transitioning the technology to Navy use in ASW. Demonstrate and report on performance during laboratory testing. The prototype will be integrated into the IWS 5.0 surface ship ASW combat system Advanced Capability Build (ACB) program, which is being used to update the AN/SQQ-89A(V)15 Program of Record.

This technology can be used in a wide range of complex systems of systems where AI/ML is used to characterize operator proficiency and just-in-time performance assistance is crucial to mission performance. The technology would be of greatest use in complex safety-critical systems where mistakes carry disproportionate risk of mission failure.

### REFERENCES:

1. Richardson, John ADM. "A Design for Maintaining Maritime Superiority 2.0," 2018.
2. Kezunovic, Mladen, et al. "The role of big data in improving power system operation and protection." 2013 IREP Symposium Bulk Power System Dynamics and Control - IX Optimization, Security and Control of the Emerging Power Grid; 1-9; IEEE.  
<https://ieeexplore.ieee.org/abstract/document/6629368>.
3. "AN/SQQ-89(V) Undersea Warfare / Anti-Submarine Warfare Combat System." United States Navy Fact File, 15 January 2019. <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166784/ansqq-89v-undersea-warfare-anti-submarine-warfare-combat-system/>.

KEYWORDS: Operator proficiency; embedded individualized support; Anti-Submarine Warfare; ASW function; detect-to-engage timeline; tactical operations

## VERSION 8

N221-028 TITLE: DIGITAL ENGINEERING - Unmanned Harbor Piloting

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 autonomous precision harbor piloting system that allows unmanned surface vehicles (USVs) to navigate safely within a channel, harbor, or strait without human intervention.

**DESCRIPTION:** Harbor piloting requires precise understanding of a vessel's current and projected position to avoid running aground. Additionally, areas such as channels, harbors, and straits are typically congested with other vessels. The current state-of-the-art in harbor piloting uses a human to integrate numerous inputs including his or her own senses of sight and hearing. Some work is currently ongoing to allow a pilot to perform this function from an off-vessel site. Innovations in process and methods by which the Navy conducts harbor piloting are required to ensure USVs are capable of safe transit in congested, confined, and constrained waterways without human intervention. These innovations will enable autonomous operations for future USVs.

The Navy seeks to develop an autonomous harbor piloting system (HPS) that will enable a USV to transit a channel, harbor, or strait without human intervention while consistently operating within the established navigational rules such as U.S. Coast Guard Navigation Rules and Regulations Handbook (COLREGS) Rules 9 and 10 [Ref 1]. This includes sensing harbor hazards and features (bridges, marine traffic, buoys, etc.) and planning a recommended route containing, at a minimum, waypoints, leg speeds, leg cross track error, and leg-to-leg turn radii. Outputs from the HPS will inform the Maneuvering Operations autonomy segment that guides the vessel's movements. The Maneuvering Operations Autonomy segment is not being developed under this SBIR topic. Harbors may include traffic schemes, restricted areas, and congested, confined, cluttered or unimproved environments with limited water depth. The HPS shall follow the preferred traffic schemes and comply with the established navigational rules based on the USV's relative position to harbor features and obstacles.

HPS concepts shall be scalable for Medium and Large USVs (MUSV and LUSV respectively) and capable of sensing harbor hazards and features (bridges, marine traffic, buoys, etc.) with a precision of 6 m (~6.5 yds.) or less, at distances from 15-100m (~16-109 yds.) from the USV, and operating at speeds less than or equal to ~ 60 kts and testing to applicable military standards (IAW MIL-STD-810H). The sensing system may use a priori information such as charts to enhance the localization and classification of harbor hazards, but it cannot solely rely on charts for obstacle and hazard avoidance. MUSV Block I has a Length Overall of about 190 feet, a beam of about 33 feet, and a displacement of about 500 LT. LUSV is still in preliminary design, but it will be larger than MUSV.

It should be assumed that current USV platforms can determine their position to within 6 meters (~6.5 yds.) and have the capability to navigate in a forward direction at 5 m/s (~10 kts) or less with a track error

## VERSION 8

of 6 meters (~6.5 yds.) or less. Additionally, the USV has a dynamic positioning system (DPS), capable of holding position within 10m (~11 yds.) and heading within 5°.

This SBIR topic seeks development of a solution that is Modular Open Systems Architecture (MOSA) compliant to allow for compatibility with future USVs. To ensure interoperability with planned and future USVs, solutions must also comply with the PMS 406's Unmanned Maritime Autonomy Architecture (UMAA). UMAA establishes a standard for common interfaces and software reuse among the mission autonomy and the various vehicle controllers, payloads, and Command and Control (C2) services in the PMS 406 portfolio of Unmanned Systems (UxS) vehicles. The UMAA common standard for Interface Control Documents (ICDs) mitigates the risk of unique autonomy solutions applicable to just a few vehicles allowing flexibility to incorporate vendor improvements as they are identified; affect cross-domain interoperability of UxS vehicles; and allow for open architecture (OA) modularity of autonomy solutions, control systems, C2, and payloads. UMAA standards and required ICDs will be provided during the Phase I effort.

Testing and certification of the route planning capability of the system will consist of autonomy simulation with a vessel of opportunity. The testing and certification of the overall performance of the system will consist of hardware-in-the-loop testing on a vessel of opportunity provided by the Government.

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

**PHASE I:** Develop a concept design for an automated harbor transit system that meets the requirements in the Description. The concept design must define a system that can consistently operate within the established navigational rules, and include any modeling and simulation, studies, or prototypes in support of concept risk reduction. Demonstrate the feasibility of the proposed concept through modeling, analysis, and concept demonstrations.

The Phase I Option, if exercised, will deliver a preliminary design of the concept, identifying the baseline design (hardware, software, support systems) and underlying architectures to ensure that the concept has a reasonable expectation of satisfying the requirements.

**PHASE II:** Based on the Phase I results and the Phase II Statement of Work (SOW), develop and deliver a prototype harbor piloting system based on the requirements in the Description. Identify the necessary interfaces, dependencies, and risks. After a successful Critical Design Review (CDR), develop a prototype system. Testing and certification of the route planning capability of the system will consist of autonomy simulation with a vessel of opportunity. The testing and certification of the overall performance of the system will consist of hardware-in-the-loop testing on a vessel of opportunity provided by the government.

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

## VERSION 8

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through system integration and qualification testing for the Navy USV harbor piloting system. UMAA-compliant precise navigation, planning, and execution systems for Navy USVs would have applicability to the commercial unmanned surface vehicles already widely in use further expanding their ability to adapt to their operational environment and conduct autonomous operations.

### REFERENCES:

1. U.S. Department of Homeland Security, “United States Coast Guard Navigation Rules and Regulations Handbook.” Rule 9 - Narrow Channels and Rule 10 Traffic Separation Schemes, 2014: 18-21. [https://www.navcen.uscg.gov/pdf/navRules/Handbook/CG\\_NAV\\_Rules\\_29Apr2020.pdf](https://www.navcen.uscg.gov/pdf/navRules/Handbook/CG_NAV_Rules_29Apr2020.pdf).
2. Caccia, Massimo, Bibuli, Marco, Bono, Riccardo et al. “Basic navigation, guidance and control of an Unmanned Surface Vehicle.” *Autonomous Robots* 25, 2008: 349–365. <https://link.springer.com/article/10.1007/s10514-008-9100-0>.
3. Liu, Zhixiang, Zhang, Youmin, Yu, Xiang, et al. “Unmanned surface vehicles: An overview of developments and challenges.” *Annual Reviews in Control* 41, 2016: 71-93. <https://www.sciencedirect.com/science/article/pii/S1367578816300219>.
4. Kolar, Parsana, Benavidez, Patrick, and Jamshidi, Mo. “Survey of Datafusion Techniques for Laser and Vision Based Sensor Integration for Autonomous Navigation.” *Sensors* 20(8), 2020: 2180. <https://www.mdpi.com/1424-8220/20/8/2180/pdf>.
5. Military Standard – Test Method Standard MIL-STD-810H “Environmental Engineering Consideration and Laboratory Tests”, Part Two – Laboratory Test Methods, 2021: 80, <https://quicksearch.dla.mil/Transient/8DC1B3C1130A4692B95448E54EF16687.pdf>.

KEYWORDS: UxV; Unmanned systems; Harbor pilot navigation; autonomous navigation; UMAA; perception sensors; datafusion; COLREGS; MOSA

## VERSION 8

N221-029 TITLE: DIGITAL ENGINEERING - Artificial Intelligence /Machine Learning Applications to STANDARD Missile Maintenance Data

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML)

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 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: Apply Artificial Intelligence (AI)/Machine Learning (ML) techniques to develop a decision aide that automates and modernizes STANDARD Missile (SM) maintenance processes and procedures with the goal of reducing life cycle costs and manpower while maintaining readiness.

DESCRIPTION: AI/ML has seen steady growth in the commercial market. Consumers see daily benefit in many areas; greater computing power as Intel, Apple, and other manufactures incorporate AI into computer processors; predictive analytics used for targeted marketing on Google and other platforms. A survey conducted by McKinsey Analytics in 2020 indicates, since 2018 greater adoption of AI principles in the manufacturing (e.g., yield, optimization, predictive maintenance) and supply chain management industries while simultaneously demonstrating 10-20% cost savings. PEO IWS and Naval Supply System Command (NAVSUP) are specifically interested in AI/ML applications in these areas, applied to the SM family.

The SM family are solid propellant, tail-controlled surface to air missiles. Variants of SM have been in production for over 20 years. For maintenance and recertification, missiles cycle through an Intermediate Level Maintenance Facility (ILMF) at NMC Seal Beach and a Depot Level Maintenance Facility (DLMF) at the Missile manufacturer, Raytheon Missiles and Defense. NSWC Corona collects missile and section level data through all maintenance and recertification periods on a Surface Missile Systems Maintenance Data System (SMSMDS) database. The SMSMDS collects, stores, and distributes missile life cycle data, including (for current and previous variants) All Up Round manufacturing and production baseline performance data, test data, re-certification reports, Trouble Reports, and Failure Reporting and Corrective Action System (FRACAS). The technology sought will enable the SM program office to optimize maintenance concepts and strategies. This in turn will allow for increased capability to the warfighter and has the potential to reduce life cycle costs by prioritizing maintenance activities at the ILMF and DLMF.

Due to the amount of SM maintenance data available, the amount of missile maintenance work required, and current fiscal constraints, the SM program office has a strong desire to use AI/ML to modernize and automate maintenance planning as well as procedures while reducing extensive man hours required to analyze SM readiness and prioritize sustainment activities. The output will serve as a decision aide for the SM program office and will assist in understanding any section level or piece part's failure's influence on the overall mission effectiveness of the system.

Currently efficiencies are dependent on personnel experience and reporting. This point of view of efficiency is very narrow and does not factor in other pieces of the entire process. Overarching aggregated



## VERSION 8

views of the entire process is at its infancy. The tool needs to be compatible with SQL server to analyze the current logistical state and an optimized state.

The Navy needs a tool to optimize SM maintenance strategies. The preferred solution will be a tool that uses AI/ML concepts such as linear regression, Decision Tree, best suited to existing SM data, which allows the user to make quicker decisions, predict reliability related failures, and identify future maintenance issues. It should also provide recommended repair processes and procedures. The tool will serve to reduce planning requirements and actions and improve procurement of spares and depot level preparation required to maintain the Fleet required load out requirements and inventory posture. Operation of the tool must be extensible to UNCLASSIFIED U.S. Navy network infrastructure. System required to comply with NIST SP 800-37 standards to include ACAS vulnerability scans and system hardening utilizing relevant DISA STIG's (i.e., Application & Security STIG and applicable OS STIG). Awardees will be required to coordinate with Government representative for specific cyber requirements.

PHASE I: Develop a concept for a SM maintenance decision aide that meets the parameters of the Description. Demonstrate the concept feasibility through analysis, modelling, and simulation. The Phase I Option, if exercised, will include the initial design specifications and a capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype SM maintenance decision aide based on the results of Phase I. Demonstrate the prototype meets the required range of desired performance attributes given in the Description. System performance will be demonstrated through installation and prototype testing on a testbed with the lead system integrator. The system will be checked for data accuracy of recorded values versus stored/calculated values. The algorithm results of the training data set will be evaluated against new data. The system optimizing capabilities metrics will be used in practice to check for concurrence.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the AI/ML tools to Navy use in the SM maintenance program to improve repair processes, procurement of spares, and depot level preparation required to maintain the Fleet required load out requirements and inventory posture. Support employing the technology developed under this SBIR topic to the Navy SM field activities. Assist in the transition of the data analytics into actionable maintenance plans and strategies for the SM program. Explore the potential to transfer the optimizing algorithm to other military and commercial systems such as automotive, aerospace, shipping, and manufacturing where logistical planning is needed.

### REFERENCES:

1. Matthew Montoya. "Standard Missile: A Cornerstone of Navy Theater Air Missile Defense"; Johns Hopkins APL Technical Digest, Vol 22 Number 3. 2001 P. 234-247.  
<https://www.jhuapl.edu/Content/techdigest/pdf/V22-N03/22-03-Montoya.pdf>.
2. Diogo Cardoso, Luís Ferreira. "Application of Predictive Maintenance Concepts using Artificial Intelligence Tools"; Applied Sciences, 2021-01-01, Vol.11 (1), p.18,  
[https://www.researchgate.net/publication/347857580\\_Application\\_of\\_Predictive\\_Maintenance\\_Concepts\\_Using\\_Artificial\\_Intelligence\\_Tools](https://www.researchgate.net/publication/347857580_Application_of_Predictive_Maintenance_Concepts_Using_Artificial_Intelligence_Tools).
3. Zeki Murat Cinar, Abubakar Abdussalam Nuhu, Qasim Zeeshan, Orhan Korhan, Mohammed Asmael, Babak Safaei. "Machine Learning in Predictive Maintenance towards Sustainable Smart Manufacturing in Industry 4.0"; Sustainability (Basel, Switzerland), 2020-10-01, Vol.12 (19), p.8211,  
<https://www.mdpi.com/2071-1050/12/19/8211>.
4. Michael Chui, Tara Balakrishnan, Bryce Hall, Nicolaus Henke, (n.d.). "The State of AI in 2020" McKinsey & Company. <https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/global-survey-the-state-of-ai-in-2020>.

## **VERSION 8**

**KEYWORDS:** Intermediate Level Maintenance Facility; Artificial Intelligence; Machine learning; STANDARD Missile; STANDARD Missile Maintenance; Decision Aide

## VERSION 8

N221-030 TITLE: DIGITAL ENGINEERING - Design for Additive Manufacturing (DfAM) Risk Toolset

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a Design for Additive Manufacturing (DfAM) toolset that will enable additive manufacturing (AM)-specific design and manufacturing-driven risk analysis within a single user interface.

DESCRIPTION: Existing DfAM tools, both for generative design and modeling and simulation, are generally employed in separate software packages. Similarly, certain aspects unique to AM are not included in many of the existing software tools currently available. Additionally, the calculation of risk due to changing the manufacturing method and materials, or utilizing a lower maturity manufacturing process, does not currently exist within many of the available design optimization software packages. Meanwhile, the AM Technical Warrant Holder (TWH) is establishing the specification and standards development for AM technology to promote process qualification and quality assurance of AM parts. This modeling toolset is needed in conjunction with these technical publications to minimize engineering risk of using AM as a replacement manufacturing method of a traditionally manufactured part.

This SBIR topic seeks a combined toolset accessible through a single user interface able to simulate the performance expectations and failure modes for various physics scenarios (e.g., static loading, thermal transfer, mass transfer, etc.) expected for a part when fabricated using AM. The desired DfAM toolset should be comprised of three modules: 1. Part specific performance modeling and simulation (M&S) as a result of manufacturing process constraints (i.e., anisotropic behavior) (henceforth “Part Performance M&S Module”), 2. Producibility, manufacturability, and manufacturing-driven generative design analysis to improve design for manufacturing, (henceforth “Optimization Module) and 3. Manufacturing process-driven risk analysis (henceforth “Risk Analysis Module”). These three modules should provide feedback to perform calculations across each module; however, each module should be able to stand independently and perform with only the minimum amount of provided inputs.

Within the Part Performance M&S Module, the orientation of the build, anisotropy of the part, and any additives/reinforcements within the build must be considered to provide an accurate expectation of part performance. The Part Performance M&S and Optimization Modules shall be able to inform the following, given the AM process, Manufacturing Readiness Level, and material being used: optimized geometry, optimized reinforcement locations and parameters, optimized infill geometry and fill percentage, and alternate additive materials/manufacturing processes.

Finally, the Risk Analysis Module shall calculate a risk analysis for using AM when compared to the original part manufacturing method, lower the risk of engineering change proposals, and inform Fleet AM designs in the deployed environment. The analysis and resulting capabilities will be used to inform technical authority and program offices on the expectation of performance comparisons between the traditional part and the AM version. In addition, part performance trade-off analyses should be able to be completed based on potential lead time and cost reduction of a design that may not achieve the same longevity or durability. The following attributes should be considered in the Risk Analysis Module (This is not an all-inclusive list. Additional attributes will be provided as Government Furnished Information (GFI) to the awarded contractors):

- Part complexity
- Traditional manufacturing method(s) if applicable
- Material performance requirements

## VERSION 8

- Manufacturing Process maturity
- Existing material and process data available
- Part performance requirements
- Part criticality (probability and severity)
- Part performance trade-off analyses (for example, reduced longevity of a part for shorter lead time and lower cost)

This toolset must provide a summary report that outlines expected key performance parameters for the part(s) under analysis and establishes a level of risk as a result of using AM to fabricate the part when compared to traditional manufacturing. A demonstration of this output report must be provided, as well as attached to the AM Technical Data Packages (in accordance with MIL-STD 31000B [Ref 1]), as appropriate. The resultant parts shall be tested for performance in accordance with the part requirements provided by the Navy to demonstrate DfAM toolset part performance prediction accuracy.

If all modules are not included in the prototype, but the contractor expects to be able to develop them, an implementation plan to include the various elements of the capabilities must be provided. User manuals instructing toolset usage, troubleshooting, and any other required information/training material to sufficiently operate the toolset must also be developed. 25 licenses of the developed product will be provided for testing and evaluation to the Navy stakeholders — 10 for NAVSEA, 10 for NAVAIR, 5 for NAVSUP.

The solution must use a model-based systems engineering approach to establish a single User Interface (UI) that can communicate with the entirety of the solution set. Government Furnished Information (GFI) in the form of a standard or guidance document will be provided to performers to ensure Defense Information Systems Agency (DISA) compliance for unclassified Research, Development, Testing, and Evaluation (RDTE) networked machines. The developed solution must comply with the DISA guidance and operate in the Windows 10 or newer operating systems with an approved Security Technical Implementation Guide (STIG) with configurable controls to meet DISA compliance requirements [Ref 7]. The toolset should be able to provide a summary report of the results in a concise format (Text, Comma separated value (CSV), Microsoft Word, Excel, other and/or Portable Document Format (PDF)) that can be included for the technical authority reviews. Finally, as the Navy works towards migration into Product Lifecycle Management (PLM) platforms, data produced within this toolset should be able to communicate with the PLM platforms. These platforms will be based on Commercial Off the Shelf (COTS) PLM programs.

A toolset to optimize various parameters within the AM process, as well as provide accurate, AM-specific, part simulations, will reduce risk of adoption of the AM technology across the NAVSEA enterprise. AM has the potential to reduce the lead time on many parts within the supply system, as well as provide an alternate manufacturing source for other parts. This flexibility, coupled with the added engineering confidence that the part will perform to the technical requirements, could result in more AM parts within the supply chain, ultimately reducing lead time for parts and increasing readiness of the warfighter.

PHASE I: Develop a conceptual program architecture and description of supporting software required to meet DfAM modules described in the Description. Demonstrate the feasibility of the concept to address the three modules. Include a description of each of the proposed models and their expected inputs and outputs. If a solution cannot support all of the modules a detailed justification to meet the described parameters listed in the Description must be provided along with a roadmap projecting how the contractor would overcome the technological gaps prohibiting completion of all three modules.

## VERSION 8

The Phase I Option, if exercised, will include the initial design specifications, capabilities description to build a prototype solution, and hardware requirements in Phase II.

PHASE II: Develop and deliver a prototype of the DfAM Risk-based toolset that demonstrates the usability of the three-module DfAM toolset. The prototype should demonstrate the intuitive user interface that supports all of the Phase I development, as well as all of the major elements listed in the Description section. The Navy will provide 1-3 use-cases to walk through the prototype solution.

The software should meet all the requirements of the Description and be able to interface with the Product Lifecycle Management (PLM) tools used by the Navy. In addition, the solution must consider hosting platforms to sustain the solution, such as enterprise software environments including the Agile Warfighter Analytics Readiness Environment (AWARE) and the Enterprise Risk Analysis & Management Tool (ERAMT) Integrated Development Environment (IDE).

PHASE III DUAL USE APPLICATIONS: Develop the final application package to include any road-mapped capabilities from Phase II. Support the Navy in transitioning the technology to Navy use. Develop a full user manual and training package. Additionally, connections to the NAVSEA method for storing and tracking material data should be possible. Application Program Interfaces (APIs) should be able to be established to make additional connections to Navy-specific databases in an effort to streamline data processing and minimize multiple sources of truth. The final transition and hosting platform, either standalone or Navy platform, will be finalized and software modified accordingly.

Additional considerations for the manufacturing location environmental variability (whether shipboard, land-based, expeditionary, or other) of the manufacturer should be able to be applied to inform a factor of safety adjustment to the simulation and design considerations. This could be used to improve robustness of AM parts manufactured in the shipboard environment, improve shipboard part certification confidence, and be leveraged by the Fleet community to inform designs of parts at-sea, as well as formalize the risk analysis procedures.

This software would be applicable to other manufacturing processes and could be leveraged by various program offices and engineering support sites. The risk analysis module could be used to inform engineering-related risk assessments that could be integrated into the Enterprise Risk Analysis & Management Tool (ERAMT).

### REFERENCES:

1. "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/](http://everyspec.com/MIL-STD/MIL-STD-10000-and-Up/MIL-STD-31000B_55788/).
2. United States Department of Navy: Naval Sea Systems Command (SEA05). (17August 2018). Letter 4870 Ser 05T/2018-024, Guidance on the Use of Additive Manufacturing.
3. American Bureau of Shipping, Guidance Notes on Additive Manufacturing, Technical Report, Houston, TX, 2018.
4. American Bureau of Shipping, Advisory on Additive Manufacturing, Technical Report Houston, TX, 2018.
5. Bendsoe, Martin Philip. author. (2013). Topology Optimization Theory, Methods, and Applications, Edition 2. Berlin, Heidelberg :Sprinter Science & Business Media
6. Bendsoe, Martin Philip. author. (2006). Solid Mechanics and its Applications: IUTAM Symposium on Topological Design Optimization of Structures, Machines, and Materials. Berlin, Heidelberg :Sprinter Science & Business Media
7. Defense Information Systems Agency (DISA) Security Technical Implementation Guide (STIG) process for Vendors. <https://public.cyber.mil/stigs/vendor-process/>.

## **VERSION 8**

**KEYWORDS:** Additive manufacturing; AM; 3D printing; modeling and simulation; geometry optimization; risk analysis; failure modes; DfAM

## VERSION 8

N221-031 TITLE: DIGITAL ENGINEERING - Distributed Mission Effectiveness and Readiness Management System

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 distributed mission effectiveness and readiness management system data analytics tool to integrate FFG 62 Model Based Systems Engineering (MBSE) and Model Based Product Support (MBPS) artifacts and/or data to present a mission effectiveness viewpoint of a single FFG 62 ship based on system readiness data.

**DESCRIPTION:** Within the framework of MBSE, models are developed to support system requirements, design, analysis, verification, and validation activities throughout the lifecycle. MBPS uses the same information along with information on support providers to optimize a platform's product support footprint, including supply chain, training, and maintenance strategy. MBSE can be leveraged to model fleet-wide effectiveness for performing missions based on technical performance characteristics, and MBPS can be leveraged to model the effectiveness of the product support footprint in supporting these missions, but the two are not often linked to optimize the decision space for the fleet. The Navy is modernizing its MBSE and MBPS toolkits, but current MBSE models do not accurately correlate product suitability data, system architecture, and Condition Based Maintenance (CBM+) data with overall mission effectiveness.

PEO USC platforms are built as an integrated System of Systems (SoS), usually comprising both Contractor Furnished Equipment (CFE) and Government Furnished Equipment (GFE) systems to deliver a complete platform architecture. PEO USC seeks to develop a methodology and a data analytics tool for analyzing, modeling, and optimizing our mission support capabilities in a proactive and predictive manner that could extend to unmanned integration or strike group operations. The solutions will facilitate performance predictions against platform mission needs of this diverse SoS architecture from an end-to-end perspective. The solution would result in a data-driven decision-making tool for FFG 62 sustainment and readiness planning, linking reliability, maintainability, and availability data with overall platform mission effectiveness and informing program Sustainment Key Performance Parameters (KPPs). The data analytics tool will aggregate MBSE data from disparate models and ontological structures to provide a platform-level view of the FFG 62's ability to meet its required missions in context of both own-ship and strike group ops.

Proposed concepts should address the ability to perform multi-platform-level and multi-mission analysis based on operational data, platform design, architecture, reliability, maintainability, and supply chain inputs. The tool should be able to handle complex functional redundancies at the platform and strike group level and provide outputs that support Program Office sustainment decisions for product support footprint, including maintenance and supply across multiple programs. Effective solutions would analyze data associated with individual systems and generate a model to predict overall performance. This would

## VERSION 8

inform Program Offices early in the acquisition cycle regarding potential performance of the platform design, and also support the decision-making process to evaluate proposed system changes. Approaches could be based on commercial SoS and Quality of Service algorithms to predict system performance, human factors analysis for usability, and dynamic systems modeling techniques. Additionally, the tool should provide information on algorithms to analyze resource decisions across multiple platforms. The tool should also interface with existing Navy CBM+ suites to perform real-time tracking and analysis of platform effectiveness. The algorithms and tools would be verified and tested at the end of each phase of the project by Government Subject Matter Experts for adequate SoS modeling through failure modeling, probability of successful mission estimation, and Monte Carlo simulation.

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

All DoD Information Systems (IS) and Platform Information Technology (PIT) systems will be categorized in accordance with Committee on National Security Systems Instruction (CNSSI) 1253, implemented using a corresponding set of security controls from National Institute of Standards and Technology (NIST) Special Publication (SP) 800-53, and evaluated using assessment procedures from NIST SP 800-53A and DoD-specific (KS) at <https://rmfks.osd.mil> (Information Assurance Technical Authority (IATA) Standards and Tools at <https://software.forge.mil/sf/projects/navy-iata>).

The Contractor shall support the Assessment and Authorization (A&A) of the system. The Contractor shall support the government's efforts to obtain an Authorization to Operate (ATO) in accordance with DoDI 8500.01 Cybersecurity, DoDI 8510.01 Risk Management Framework (RMF) for DoD Information Technology (IT), NIST SP 800-53, NAVSEA 9400.2-M (October 2016), and business rules set by the NAVSEA Echelon II and the Functional Authorizing Official (FAO). The Contractor shall design the tool to their proposed RMF Security Controls necessary to obtain A&A. The Contractor shall provide technical support and design material for RMF assessment and authorization in accordance with NAVSEA Instruction 9400.2-M by delivering OQE and documentation to support assessment and authorization package development.

Contractor Information Systems Security Requirements. The Contractor shall implement the security requirements set forth in the clause entitled DFARS 252.204-7012, "Safeguarding Covered Defense Information and Cyber Incident Reporting," and National Institute of Standards and Technology (NIST) Special Publication 800-171.

PHASE I: Develop a concept that can meet the design constraints listed in the Description section. Establish feasibility by developing models that show the system architecture and operational concept of the tool. Feasibility will also be established by computer-based simulations that show the tool's capabilities are suitable for the project needs. Example inputs for Phase I include system-of-systems diagrams in XML, reliability, maintainability, and cost information associated with the systems, and notional mission profiles as they apply to the systems. The output concept should link the inputs in an architecture that displays platform systems design characteristics and information on required



## VERSION 8

functionality for mission effectiveness. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I and the Phase II Statement of Work (SOW), the company will develop, demonstrate, and deliver a comprehensive modeling tool prototype that can perform platform-level mission analysis based on system design, system architecture, and mission engineering concepts linking reliability, maintainability, and supply chain inputs. The tool should provide outputs that support program acquisition and sustainment decisions for product support logistics footprint, including maintenance and supply. The prototype solution shall be based on a data architecture that establishes relationships between individual systems, associated design characteristics, acquisition cost, and sustainment footprint. Evaluate the tool's effectiveness in linking disjointed and disparate data sources into a cohesive model for evaluation and its ability of the model to support decision-making and 'what-if' analysis to determine whether the models meet performance goals as defined. Demonstrate the tool's performance through prototype testing and detailed analysis, including mission thread analysis and failure mode analysis with verification through Monte Carlo simulations. Prepare a Phase III development plan to transition the technology to Navy use.

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

PHASE III DUAL USE APPLICATIONS: Support the Navy to transition the multi-platform, multi-mission modeling capability tool from stand-alone application to application integrated with Department of Navy and PMS 515 MBSE and MBPS efforts, including CBM+ systems. Assist with integration aboard fielded platforms for real time analysis of mission effectiveness to support decision makers in the fleet. Program offices and Navy Type Commanders (TYCOMs) can use the tool to better understand impacts of lack of resources or to support reallocation of resources, or resources or assess to probability of mission success in a highly complex environment. Commercial applications of the tool would include other multi-use and/or multi-nodal systems, including air, ground, and maritime vehicles, computing infrastructure, and other uses where optimizing operational time across a wide array of assets is beneficial.

### REFERENCES:

1. Madni, A.M., Madni, C.C., and Lucero, S.D. "Leveraging Digital Twin Technology in Model-Based Systems Engineering." *Systems* 2019, 7, 7. <https://doi.org/10.3390/systems7010007>.
2. Bickford, Jason, et al. "Operationalizing digital twins through model-based systems engineering methods." *Systems Engineering* 23.6 (2020): 724-750. <https://onlinelibrary.wiley.com/doi/abs/10.1002/sys.21559>.
3. Crane, Jeremiah, et al. "MBSE for sustainment: A case study of the air force launch and test range system (LTRS)." *AIAA SPACE and Astronautics Forum and Exposition*. 2017. <https://arc.aiaa.org/doi/pdf/10.2514/6.2017-5302>.
4. Beery, Paul, and Eugene Paulo. "Application of model-based systems engineering concepts to support mission engineering." *Systems* 7.3 (2019): 44. <https://www.mdpi.com/2079-8954/7/3/44>.

KEYWORDS: Model Based Systems Engineering; Model Based Product Support; Mission Engineering; Operational Availability; Readiness, Sustainment; Product Support; Distributed; Mission Effectiveness; System Optimization

## VERSION 8

N221-032 TITLE: DIGITAL ENGINEERING - 3D Operator Decision Aides for Ship Control Systems

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Information Systems

**OBJECTIVE:** Develop an automated operator decision aide capability for ship control systems that improves situational understanding through the use of a single 3D visualization system to reduce cognitive burden; enable and provide an aggregate viewpoint of system and platform health; and enable data-driven decision making.

**DESCRIPTION:** As the Navy continues to reduce manpower requirements associated with operating ever-increasing technologically complex systems, new methods that enable natural and intuitive 3D interaction with ship control systems' data are desired to aid in reducing the overall operator burden and enhance watch stander situational awareness. Developing an optimized capability to engage and process a ship's information from multiple systems in a high-stress environment will allow the operators to increase task accuracy, reduce response time, and increase overall situational awareness.

This SBIR topic seeks an automated operator decision aide capability for ship control system logic that improves bridge watch stander situational understanding through the integration of data from multiple ship systems and use of 3D visualization techniques. New approaches are needed to reduce operator burden through the application of enhanced visualization methods and dynamic real-time, temporally accurate visualizations of ship systems. By presenting complex data in a user-friendly, yet informative, manner, the cognitive load on the operator can be decreased and the ability to make data-driven decisions based on complicated information is improved. Approaches are encouraged to apply Artificial Intelligence (AI) and Machine Learning (ML) as practicable.

Automated operator decision aides will convert various ship systems' data and sensor outputs into a human-readable and intuitive User Experience (UX) to provide an aggregate viewpoint of the overall ship system and platform health. This will enable operators to visualize the mission impact of ship control system status (e.g., up/down, failure mode, performance). The automated operator decision aides should categorize and prioritize information display with the goal of compiling, automating, and reducing burdens on the decision makers to assist them in understanding a component failure's influence on the overall mission effectiveness of the system. The automated operator decision aides will also display the integrated logic functions associated with the systems' permissive and alarms and inform operators of these failures to enable a data driven decision making process and allow for immediate corrective actions.

The automated operator decision aide system must be capable of collecting all ship control systems' data and must include an interface to support data export. This will enable data analysis by the Program Office, In-Service Engineering Agents (ISEAs), and subject matter experts. The data can be used to track failures, help find mitigation plans to avoid future failures, and inform maintenance and logistical requirements. Proposers should develop a solution that is Modular Open Systems Approach (MOSA)-compliant to allow for cross-platform compatibility and future capability improvements. Because of the unique and specific nature of the multiple FFG 62 subsystems, of which data will be collected, no commercial solutions to allow for subsystem data integration and/or data exportation currently exist. Testing will be iterative throughout the phases in order to test accurate data consolidation, user experience, and secure cyber footprint. Specifically, this solution must have the ability to achieve Navy accreditation and certification in order to be installed on an operational vessel in accordance with the latest guidance including, but not limited to, Authorization to Operate and Risk Management Framework policies.

## VERSION 8

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

All DoD Information Systems (IS) and Platform Information Technology (PIT) systems will be categorized in accordance with Committee on National Security Systems Instruction (CNSSI) 1253, implemented using a corresponding set of security controls from National Institute of Standards and Technology (NIST) Special Publication (SP) 800-53, and evaluated using assessment procedures from NIST SP 800-53A and DoD-specific (KS) at <https://rmfks.osd.mil> (Information Assurance Technical Authority (IATA) Standards and Tools at <https://software.forge.mil/sf/projects/navy-iata>).

The Contractor shall support the Assessment and Authorization (A&A) of the system. The Contractor shall support the government's efforts to obtain an Authorization to Operate (ATO) in accordance with DoDI 8500.01 Cybersecurity, DoDI 8510.01 Risk Management Framework (RMF) for DoD Information Technology (IT), NIST SP 800-53, NAVSEA 9400.2-M (October 2016), and business rules set by the NAVSEA Echelon II and the Functional Authorizing Official (FAO). The Contractor shall design the tool to their proposed RMF Security Controls necessary to obtain A&A. The Contractor shall provide technical support and design material for RMF assessment and authorization in accordance with NAVSEA Instruction 9400.2-M by delivering OQE and documentation to support assessment and authorization package development.

Contractor Information Systems Security Requirements. The Contractor shall implement the security requirements set forth in the clause entitled DFARS 252.204-7012, "Safeguarding Covered Defense Information and Cyber Incident Reporting," and National Institute of Standards and Technology (NIST) Special Publication 800-171.

PHASE I: Develop a concept for an automated operator decision aide that integrates data from multiple ship systems with a 3D visualization and export capability. The concept must show that it can feasibly meet the requirements of the Description. Establish feasibility through modeling and simulation of the concept.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Fabricate a comprehensive automated decision aide prototype that is capable of demonstrating the implementation and integration into the ship system environment for testing and evaluation. Demonstrate accuracy, repeatability, and functionality, adhering to the requirements outlined in the Description. Perform a system demonstration in a simulated environment.

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

## VERSION 8

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use and support further refinement and testing of the automated operator decision aide's functionality following successful prototype development and demonstration. Testing will be accomplished by real-time demonstration of the developed capability with operational users in order to gauge successful metrics for accuracy, readability, and implementation of data feeds into a singular user interface. Upon capability demonstration and quantifiable test results, direct the focus toward the transition and integration of the technology into Bridge and Machinery Control Systems.

This solution has applicability across the Navy on other platforms with complex/automated ship control systems such as Unmanned Vehicles (UxVs) and could help to increase both mission effectiveness and readiness. This capability can be applied to commercial applications with diverse and complex human-in-the-loop interfaces, including aviation and commercial maritime operations.

### REFERENCES:

1. Scherer, Timothy and Cohen, Jeffrey. "The Evolution of Machinery Control Systems Support at the Naval Ship Systems Engineering Station". Naval Engineers Journal. 18 May 2011. Volume 2: 85-109.
2. Wright, R. Glenn. "Virtual Aids to Navigation". World Maritime University. 2017. [https://commons.wmu.se/phd\\_dissertations/14/](https://commons.wmu.se/phd_dissertations/14/).
3. Balogh, P., Kovacs, P. T., and Barsi, A. "Holovizio 3D Display System." 2007 3DTV Conference. 07-09 May 2007. DOI: 4379386

KEYWORDS: Ship control system; virtual environment; 3D visualization; interactive shipboard; system logic functions; virtual watchstander.

## VERSION 8

N221-033 TITLE: DIGITAL ENGINEERING - Perception System for Situational Awareness and Contact Detection for Unmanned Underwater Vessels

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 sense and avoid perception system for unmanned underwater vessels (UUVs) to support the safe maneuvering and navigation in both the surface and the undersea domains.

DESCRIPTION: A UUV needs to surface periodically to get GPS fixes, charge batteries, or communicate with other vessels and buoys. Before surfacing a UUV must identify potential surface or near-surface contacts, obstacles or features to ascertain if the environment is safe for the vehicle to ascend and conduct operations.

The Navy is seeking to develop and demonstrate a sense and avoid perception processing system for small-class UUVs as categorized in the Navy's report to Congress on Autonomous Undersea Vehicle Requirement for 2025 [Ref 1]. The system will enable the UUV to detect, classify, track, and estimate risk of contact with surface and undersea vessels operating in proximity. The solution must be scalable for future adaptation on larger unmanned system platforms including medium-class and larger UUVs. No current commercial technologies exist that have the military applications that the Navy seeks.

The perception processing system will utilize onboard sensors to provide the UUV 360 degree situational awareness both on and near the water's surface to enable the vehicle to safely surface or avoid a collision. The system must be able to process the raw data and provide the contact attributes as an output to an onboard autonomous control system to support obstacle/collision avoidance.

Contacts may include all sizes of power and sailing vessels, buoys and other navigation markers, and structures. Attributes may include but are not limited to contact size, height to length ratio, range, bearing, and speed/direction. The perception processing system should be capable of measuring a contact's relative position information, rate of change of relative position, and/or the trajectory information to decide whether a risk of collision exists and if an avoidance maneuver is required. These measurements and projections of future movements include varying degrees of uncertainty. An estimate of the uncertainty is valuable in assessing when sufficient information is available to make a maneuver decision. The decision timeline is time-constrained but the reaction time to successfully evade. Maneuver decisions must be made early enough to ensure safe separation. Additionally the system should be capable of tracking surface or near-surface objects and their attributes to maintain awareness of potential surface contacts within 10 nautical miles of UUV objective areas that are closing on the location of UUV(s). Concepts proposing additional external sensors as a portion of their solution must do so without adversely impacting trim, balance, or hydrodynamic performance of the target host platform and should offer solutions requiring 50w or less power.

## VERSION 8

The solution may be software or a combination of software, hardware processors, and sensors necessary to support operation of the developed perception algorithms. For the initial phase of this SBIR topic, prefer solutions suitable for with small-class (7.5” diameter) expeditionary UUVs, which are two-person carry in size and weight in accordance with MIL-STD 1472 section 5.8 [Ref 2]. Application of artificial intelligence/machine learning (AI/ML) and other digital engineering techniques are desired. As an element of the seminal transition event in Phase II, testing of the key performance parameters and key system attributes will be conducted in a relevant environment to verify that the capabilities of the system were satisfied.

To ensure interoperability with planned and future unmanned systems, solutions must also comply with DoN’s Unmanned Maritime Autonomy Architecture (UMAA) [Ref 3]. UMAA establishes a standard for common interfaces and software reuse among the mission autonomy and the various vehicle controllers, payloads, and Command and Control (C2) services for unmanned systems (UxS) vehicles. The UMAA common standard for Interface Control Documents (ICDs) mitigates the risk of unique autonomy solutions applicable to just a few vehicles allowing flexibility to incorporate vendor improvements as they are identified; effects cross-domain interoperability of UxS vehicles; and allows for open architecture (OA) modularity of autonomy solutions, control systems, C2, and payloads. UMAA standards and required ICDs will be provided during the Phase I effort.

**PHASE I:** Develop a concept design for the automated perception processing system that meets the requirements in the Description. The concept design must define a system that can consistently sense, perceive, and report surface objects and vessels and include any modeling and simulation, studies in support of concept risk reduction. Demonstrate the feasibility of the proposed concept through modeling, analysis, and concept demonstrations. Feasibility studies in Phase I will be oriented at solutions for small class UUVs, but should assess scalability for future medium-class UUVs and other expeditionary unmanned systems.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop, deliver, and integrate perception processing prototype system capabilities for demonstration and characterization of key performance parameters, key system attributes, and objectives. Based on lessons learned in Phase II through the prototype demonstration, integrate the perception processing system into unmanned surface vessel of opportunity, deliver the prototype solution, and demonstrate feasibility of the concept and functionality of the autonomy.

**PHASE III DUAL USE APPLICATIONS:** Incorporate design improvements from the Phase II demonstration efforts and assist the Navy in transitioning the technology to Navy use. Fabricate and deliver prototype software with integrated Navy provided UUV and USV. Independent testing and evaluation will be conducted by the Navy in cooperation with Fleet end user community to validate effectiveness and suitability for transition and fielding. Autonomy and products developed and demonstrated under this initiative provide potential solutions for other unmanned surface and undersea systems across the Navy portfolio and throughout commercial activities in including offshore oil and gas pipeline inspection and undersea survey, search, salvage and recovery, and port security companies; and in other Government agencies employing unmanned systems.

### REFERENCES:

1. “Secretary of the Navy Report to Congress: Autonomous Undersea Vehicle Requirement for 2025.” dated 18 February 2016. <https://news.usni.org/wp-content/uploads/2016/03/18Feb16-Report-to-Congress-Autonomous-Undersea-Vehicle-Requirement-for-2025.pdf>.

## VERSION 8

2. “Department of Defense Design Criteria Standard, Human Engineering (MIL-STD 1472F), 23 Aug 1999.” <http://chassis-plans.com/PDF/MIL-STD-1472F.pdf>.
3. PEO Unmanned and Small Combatants (PEO USC); Unmanned Maritime Autonomy Architecture (UMAA), Architecture Design Description (ADD); 29 Dec 2019.
4. DON Innovation. “The Expeditionary MCM (ExMCM) Company: The Newest Capability in U.S. Navy Explosive Ordnance Disposal (EOD) Community.” July 2017. <https://www.secnav.navy.mil/innovation/Documents/2017/07/ExMCM.pdf>.

KEYWORDS: Underwater Unmanned Vehicle (UUV); Unmanned Surface Vehicle (USV); Autonomous Unmanned Vehicle (AUV); Perception; Autonomy

## VERSION 8

N221-034 TITLE: DIGITAL ENGINEERING - Combatant Craft Autonomy-Enabling Sensors, Perception and Command & Control

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Ground / Sea Vehicles

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

OBJECTIVE: Develop a sensor, perception, and Command and Control (C2) suite suitable and sufficient for enabling combatant craft mission-specific autonomous behaviors.

DESCRIPTION: The Navy's Maritime Expeditionary Security Force (MESF) provides port and harbor security, and high value asset security inland, on coastal waterways and ashore. Advanced unmanned autonomous patrol craft would help reduce risks to boat crews and enable unique new operational capabilities. The operating environments and mission requirements for these craft differ significantly from open ocean missions, which are the focus of many current Navy autonomous vessel development efforts. Specifically, the Navy needs a small form factor sensor, perception, and C2 suite to enable autonomy for combatant craft addressing the unique challenges of their mission sets. New proposed system must meet Size, Weight, Power and Cost (SWaP-C) of existing systems if applicable.

Current sensors and perception software for Unmanned Surface Vessels (USVs) lack the ability to conduct precision close-in tracking of small vessels for fine-tune and/or high relative speed maneuvering. They are also unable to sufficiently sense and characterize a potential threat vessel or individuals on it, or make a determination of a potential threat's intent, either for reporting to a human operator or triggering autonomous vessel responses.

Many potential sensor/perception technologies exist that may be suitable for these particular challenges. For the sake of example, but not to limit the scope of potential proposed solutions, a Light Detection and Ranging (LIDAR) system or radar system may be appropriate for close-in tracking to enable autonomous maneuvering near or in contact with another vessel, or an Electro Optical/Infra-Red (EO/IR) camera with advanced image recognition capabilities may be appropriate for characterizing contact vessels and establishing probable intent. Many candidate LIDAR and EO/IR camera systems are already commercially available for other applications (e.g., LIDAR for agricultural surveying, radars in use for car traffic detection and lane assist systems, or EO/IR cameras for fixed site security).

Analysis and development is also required to optimize a system to allow high level C2 of multiple varied types of combatant craft, both manned and unmanned, when equipped with autonomy software and controllers. This includes a mesh networking (or other suitable) communications system, a Common Operating Picture (COP), and C2 interface. The C2 interface must provide clear indications to human operators of the current threats perceived and high-level behaviors being executed by autonomous craft and allow dynamic tasking/re-tasking of high-level behaviors from human operators to the autonomous craft.



## VERSION 8

These capabilities should be suitable for integration on a variety of small combatant craft. Size and weight should be minimized, notionally not to exceed one half a standard electronics rack, with smaller electronics solutions preferred. Similarly, deck space for integration of sensors is at a premium, so smaller and/or less-invasive options are preferred. Power consumption should also be minimized to the extent possible.

Target platforms for transition include the 40 PB (40 foot patrol boat), Rigid Inflatable Boats (RIBs), MK VI Patrol Boat, etc., and/or existing small autonomous vessels, e.g., the Common Unmanned Surface Vehicle (CUSV).

A variety of autonomous vehicles and autonomy software frameworks already exist, in various states of development and employment. Many of these are commercial proprietary and tied to specific autonomous vehicles, such as the Leidos autonomy developed for the SeaHunter program. While not prescriptive of any particular vessel or framework, it is the hope for this effort to leverage one or more existing capabilities to the maximum extent practical. This reduces the scope to focus specifically on the immature components of sensing, perception, and C2 as applied to combatant craft operations. One potential system is the Control Architecture for Robotic Agent Command and Sensing (CARACaS), originally developed by NASA's Jet Propulsion Laboratory for the Office of Naval Research (<https://www-robotics.jpl.nasa.gov/tasks/showTask.cfm?FuseAction=ShowTask&TaskID=271&tdaID=700075>).

**PHASE I:** Develop a concept for an advanced sensor, perception, and C2 suite suitable for integration on a variety of existing or future combatant craft and integration with an existing vessel autonomy framework. Demonstrate the viability of the concept in meeting Navy requirements, as described above, and will establish that the system can be feasibly developed into a useful product for the Navy. Feasibility will be established by engineering analysis, component and system level modeling and simulation, and component technology maturity assessments. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Based on the results of Phase I and the Phase II Statement of Work (SOW), develop and deliver a prototype to the Navy for evaluation in meeting the performance goals defined in the Phase II SOW and the Navy requirements for a combatant craft sensor, perception, and C2 suite. Conduct on-water testing as well as modeling or analysis to demonstrate system performance over the required range of parameters. This will allow the government team to evaluate the system's ability to meet the performance goals defined in the Phase II SOW and the Navy requirements for the system. On-water testing location(s) will be negotiated between the small business and government team for reasons of proximity to both parties, weather/current conditions, availability of instrumented ranges, etc. Evaluation results will be used in collaboration with the Navy design team to refine the prototype into a design that will meet Navy needs. Conduct performance integration and risk assessments, and develop a cost benefit analysis and cost estimate for a naval shipboard system. Prepare a Phase III development plan to transition the technology to Navy and potential commercial use.

**PHASE III DUAL USE APPLICATIONS:** Support the Navy in transitioning the technology to Navy use and determine appropriate system components/variants for shore-side operation and installation on various craft. Support required modifications for integration, performance and environmental testing, and required certifications (e.g., electronic interference mitigation, battery safety, etc., as applicable). This includes providing component manufacturer information and specifications and/or testing components to verify regulations compliance. Target platforms for transition include the 40 PB (40 foot patrol boat), Rigid Inflatable Boats (RIBs), MK VI Patrol Boat, etc., and/or existing small autonomous vessels, e.g., the CUSV.

## VERSION 8

Other potential targets for transition include U.S. Coast Guard patrol craft, which have similar mission sets, and commercial vendors for related applications, for example, pleasure or fishing boats. Additional potential transition targets include universities or research institutions studying and/or employing small autonomous craft.

### REFERENCES:

1. Ansary, Jamal, et al. "Swarms of Aquatic Unmanned Surface Vehicles (USV), a Review From Simulation to Field Implementation." Proceedings of the ASME 2020 International Design Engineering Technical Conference and Computers and Information Engineering Conference. Volume 2: 16th International Conference on Multibody Systems, Nonlinear Dynamics, and Control (MSNDC). Virtual, Online. August 17-19, 2020. V002T02A029. ASME. <https://doi.org/10.1115/DETC2020-22702>.
2. Halterman, Ryan and Bruch, Michael "Velodyne HDL-64E lidar for unmanned surface vehicle obstacle detection", Proc. SPIE 7692, Unmanned Systems Technology XII, 76920D. 7 May 2010; <https://doi.org/10.1117/12.850611>.
3. Schaus, Brian M. Improving maritime domain awareness using neural networks for target of interest classification. Naval Postgraduate School Thesis. Monterrey, CA. 2015. <http://hdl.handle.net/10945/45252>.
4. See, Hongze Alex. Coordinated guidance strategy for multiple USVs during maritime interdiction operations. Naval Postgraduate School Thesis. Monterrey, CA. 2017. <http://hdl.handle.net/10945/56175>.

KEYWORDS: Autonomy; image recognition; threat detection; Command and Control; Manned Unmanned Teaming; high value unit escort.

## VERSION 8

N221-035 TITLE: DIGITAL ENGINEERING - Multi-Beam Antenna Scheduling Optimization

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 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 algorithmic approach to optimally schedule transmit/receive communications in a command-and-control network using multi-beam antennas.

**DESCRIPTION:** Existing Navy command and control networks create a force-level track picture by fusing sensor measurements from all members of the deployed group. The measurements are sent from the sensing unit to all other units by a series of pairwise exchanges using directional, single-beam antennas. Command and control networks use time-division multiple access (TDMA) to create the pairwise, transmit/receive schedule to send measurements from each sensor to all other sensors in the network for fusion. Command and control networks also support the flow of sensor data to directly support Engage on Remote (EOR), which requires more dedicated information exchange to achieve required latencies.

New antenna technologies are being developed that permit multiple beams to be formed by the antenna array, providing the possibility to transmit or receive simultaneously in multiple beams. Creating such an antenna, compatible with the existing command and control networks, is a significant technological development. The development of a new transmit/receive scheduling method is required to derive operational benefit from this technological development. There are no known current solutions that addresses this developed technology need. A solution is needed to develop an algorithmic approach to optimally schedule transmit/receive communications in a command-and-control network using multi-beam antennas.

Several possible configurations are of interest. Configuration 1 contains one unit with a multi-beam antenna while the remaining units have single beam antennas. Configuration 2 contains a random mix single-beam and multi-beam antennas. Configuration 3 is composed entirely of multi-beam antennas. These configurations are representative of the evolution from an initial operational capability to a final operational capability of the new antenna technology. It is required that a single scheduling approach be able to support all configurations.

The term multi-beam can be interpreted to mean 2 beams, but the ability to scale the scheduling concept to a larger number of beams must be addressed. The intent is to demonstrate, in modeling and simulation, improved network performance using the multi-beam scheduling versus single-beam scheduling. Network performance metrics must be defined to quantify the performance improvement of the various multi-beam configurations relative to the single beam configuration.

Media Access Control (MAC) protocols for multi-beam antennas are discussed in the Wang and Kuperman references. These approaches may be relevant for the exchange of track measurements among

## VERSION 8

units to produce the fused track picture. The Raviv reference discusses the inclusion of priorities and deadlines in the schedule creation, which may be relevant to scheduling transmission of EOR support data. A single scheduling approach that supports both track measurements and EOR data is required. The solution will be validated by testing in a laboratory environment which will be provided by the performer. The prototype solution will be delivered to the Navy for further testing and development assisted by the performer.

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

PHASE I: Develop a concept for an algorithmic approach to optimally schedule transmit/receive communications and demonstrate the concept meets the parameters in the Description. Concept feasibility will be demonstrated through analysis, modelling, and simulation. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop, demonstrate, and deliver a prototype algorithmic approach to optimally schedule transmit/receive communications based on the results of Phase I. Demonstrate the prototype meets the parameters described in the Description through testing in a laboratory environment. The laboratory environment will be provided by the performer.

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. The scheduling concept will be merged with existing command and control software to assist in generating the TDMA transmit/receive schedule. Working prototype scheduling algorithms, will be delivered to the Navy for testing and further development. Work with the program of record prime contractor for integration into the scheduling algorithm to be deployed. The prime contractor will be responsible for integrating the suite of scheduling concepts that best support the requirements of the network capability to be deployed in conjunction with the company assisting in the integration processes.

This technology will also benefit commercial radio industries that have a need to handle many transmissions at the same time over networks.

### REFERENCES:

1. Wang, Gang, Yanyuan, Qin. "MAC Protocols for Wireless Mesh Networks with Multi-beam Antennas: A Survey," Future of Information and Communication Conference 2019/02/02, doi: 10.1007/978-3-030-12388-8.  
[https://www.researchgate.net/publication/337774271\\_MAC\\_Protocols\\_for\\_Wireless\\_Mesh\\_Networks\\_with\\_Multi-beam\\_Antennas\\_A\\_Survey](https://www.researchgate.net/publication/337774271_MAC_Protocols_for_Wireless_Mesh_Networks_with_Multi-beam_Antennas_A_Survey).
2. G. Kuperman, R. Margolies, N. M. Jones, B. Proulx and A. Narula-Tam, "Uncoordinated MAC for Adaptive Multi-Beam Directional Networks: Analysis and Evaluation," 2016 25th

## VERSION 8

International Conference on Computer Communication and Networks (ICCCN), Waikoloa, HI, USA, 2016, pp. 1-10, doi: 10.1109/ICCCN.2016.7568593.

<https://ieeexplore.ieee.org/document/7568593>.

3. Raviv, Li-on, Leshem, Amir. "Scheduling for Multi-User Multi-Input Multi-Output Wireless Networks with Priorities and Deadlines," 2019/08/05, doi: 10.3390/fi11080172.

[https://www.researchgate.net/publication/334979274\\_Scheduling\\_for\\_Multi-User\\_Multi-Input\\_Multi-Output\\_Wireless\\_Networks\\_with\\_Priorities\\_and\\_Deadlines](https://www.researchgate.net/publication/334979274_Scheduling_for_Multi-User_Multi-Input_Multi-Output_Wireless_Networks_with_Priorities_and_Deadlines).

KEYWORDS: Multi-beam antenna; transmit/receive scheduling; fused track picture; pairwise exchange; time-division multiple access (TDMA); media access control

## VERSION 8

N221-036 TITLE: DIGITAL ENGINEERING - Exploitation of Ephemeral Features in Sonar Classification Algorithms

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 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 automated classification techniques that improve performance with ephemeral features in active and passive sonar systems.

DESCRIPTION: In active and passive sonar systems, automated processing can include classification algorithms to reject false alarms (that is, clutter) while retaining true target detections.

State of the art classification algorithms are, in general, multiple hypothesis tests that can be implemented by extracting features from the acoustic measurement associated with each detected "contact". The features distill different characteristics of the measured sound such as aural features or descriptive features, similar to how arches, loops, and whorls help classify fingerprints. In automated sonar systems, the features extracted from a sonar contact are typically combined using non-linear algorithms to identify the class to which the contact belongs. In most cases, these algorithms have parameters that must be learned (that is, the classifier is trained) through analysis of existing data that has already been labeled as to its class.

The availability of off-the-shelf classifiers such as multiple hypothesis testing and machine learning tools, has enabled the development and testing of numerous features. A limitation of most off-the-shelf algorithms is that they typically assume every feature is available all the time. However, not all features are viable in every contact. Some are missing only occasionally and some only occur rarely (that is, ephemeral features). An example of such an ephemeral feature in facial recognition would be the shape of the nose, mouth, and chin during time when some are wearing masks. Sonar similarly has such recognition features that may be missing, either because the environment masks the feature or because submarines, trying to be stealthy by design, try to hide such "features." The standard approaches for handling this missing-data problem deal with it indirectly (such as, by replacing the missing feature with its mean over the training data). They may also incorrectly assume missing features occur in a uniformly random manner throughout the data. As such, the standard approaches to missing data do not fully exploit the information contained in ephemeral features when they exist. Expanding sonar classification to include ephemeral features (features that are not always present) will give Navy systems increased capacity 1) to detect stealthy submarines or torpedoes that may not otherwise be detected or 2) to accelerate detection of targets in cases where time to react is limited and the consequences of delayed detection are potentially fatal.

One system where ephemeral features exist is the AN/SQQ-89A(V)15, which contains functions for pulsed active sonar, continuous active sonar, towed array passive sonar, and hull array passive sonar.

## VERSION 8

Technology developed under this topic should be extensible to each of these functions, with initial adoption most likely to occur within the pulsed active sonar function.

The ideal solution will exploit off-the-shelf classifier technology, have practical implementation and training procedures, and handle features that occur rarely or frequently. As real-world data sets associated with the AN/SQQ-89A(V)15 are classified, companies are encouraged to plan to obtain or generate unclassified data sets that demonstrate their solution.

While proposers are encouraged to demonstrate the power of their approach on unclassified data they have obtained, created, or simulated, the Phase II effort will involve tests of the technology developed under this topic with recorded data provided by the Navy both to assess stand-alone performance, as well as provide for the technology to be assessed within the overall sonar processing string. Details of exactly how this is to occur will be dependent on the nature of the proposed technology. Once the technology is independently deemed to provide value, the Navy will commit to incorporating the technology into a future sonar system build, which will go through certification as an integrated system.

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

**PHASE I:** Develop a concept for improved sonar classification algorithms with ephemeral features that meet the parameters of the Description. Demonstrate the feasibility of the concept through modelling, analysis, and simulation. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Develop and deliver a prototype improved sonar classification algorithm with ephemeral features based on the results of the research in Phase I. Demonstrate the prototype meets the required range of desired performance attributes given in the Description. System performance will be demonstrated through installation and prototype testing on a testbed with the lead system integrator.

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

**PHASE III DUAL USE APPLICATIONS:** Assist the Navy in transitioning the technology for Navy use in an operationally relevant environment to allow for further experimentation and refinement. The prototype algorithm will be integrated into the PEO-IWS 5 surface ship ASW combat system Advanced Capability Build (ACB) program used to update the AN/SQQ-89 Program of Record.

Commercial applications that could benefit from ephemeral features of sonar classification algorithms include both active and passive remote-sensing systems where the data includes ephemeral features. Examples outside of sonar include most applications of radar, lidar, satellite remote sensing, ultrasound, and thermal imaging.

REFERENCES:

## VERSION 8

1. Young, V. W. and Hines, P. C., "Perception-based automatic classification of impulsive-source active sonar echoes," Journal of the Acoustical Society of America, 122:3, pp. 1502-1517, September 2007. For libraries local to you holding this article, see [https://www.worldcat.org/title/perception-based-automatic-classification-of-impulsive-source-active-sonar-echoes/oclc/211513436&referer=brief\\_results](https://www.worldcat.org/title/perception-based-automatic-classification-of-impulsive-source-active-sonar-echoes/oclc/211513436&referer=brief_results), accessed 3/31/2021.
2. Murphy, S. M. and Hines, P. C., "Examining the robustness of automated aural classification of active sonar echoes," The Journal of the Acoustical Society of America, 135:2, pp. 626-636, February 2014. For libraries local to you holding this article, see [https://www.worldcat.org/title/examining-the-robustness-of-automated-aural-classification-of-active-sonar-echoes/oclc/5537024626&referer=brief\\_results](https://www.worldcat.org/title/examining-the-robustness-of-automated-aural-classification-of-active-sonar-echoes/oclc/5537024626&referer=brief_results), accessed 3/31/2021.
3. Buss, M., Benen, S., Stiller, D., Kraus, D. , and Kummert, A. , "Feature selection and classification for false alarm reduction on active diver detection sonar data," in Proceedings of 4th Underwater Acoustics Conference and Exhibition (UACE2017), pp. 569-576, 2017. At [https://www.uaconferences.org/docs/Past\\_proceedings/UACE2017\\_Proceedings.pdf](https://www.uaconferences.org/docs/Past_proceedings/UACE2017_Proceedings.pdf), accessed 3/31/2021.
4. Hastie, T. , Tibshirami, R. , and Friedman, J. , The Elements of Statistical Learning, Springer, 2009. For libraries local to you holding this article, see [https://www.worldcat.org/title/elements-of-statistical-learning-data-mining-inference-and-prediction/oclc/1080370824&referer=brief\\_results](https://www.worldcat.org/title/elements-of-statistical-learning-data-mining-inference-and-prediction/oclc/1080370824&referer=brief_results), accessed 3/31/2021.
5. Eibe Frank, Mark A. Hall, and Ian H. Witten (2016). The WEKA Workbench. Online Appendix for "Data Mining: Practical Machine Learning Tools and Techniques", Morgan Kaufmann, Fourth Edition, 2016. For libraries local to you holding this book, see [https://www.worldcat.org/title/data-mining-practical-machine-learning-tools-and-techniques-ed-4/oclc/1242613909&referer=brief\\_results](https://www.worldcat.org/title/data-mining-practical-machine-learning-tools-and-techniques-ed-4/oclc/1242613909&referer=brief_results), accessed 6/3/2021 Weka 3: Machine Learning Software in Java is available at <https://www.cs.waikato.ac.nz/ml/weka/>, accessed 3/31/2021.

KEYWORDS: Classifier; sonar contact; ephemeral features of sonar; classification algorithms; machine learning, multiple hypothesis testing



## VERSION 8

N221-037 TITLE: Compact Electron Beam Focusing System for Millimeter Wave Sources

OUSD (R&E) MODERNIZATION PRIORITY: Directed Energy (DE)

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 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 low-voltage, high-current, round-beam electron gun that significantly reduces the size and weight of high-power W-band traveling-wave tube amplifiers.

DESCRIPTION: Traveling Wave Tubes (TWTs) are the primary radiofrequency (RF) power amplifiers used in applications that require both high output power and wide bandwidth (large power-bandwidth product). However, systems that employ these critical components at high millimeter-wave (mmW) frequencies, up to and including W-band (75-110 GHz), are especially difficult to realize in low size, weight, and power (SWaP) form factors. They are also extremely costly. This is due to the extremely small size of the high-frequency RF components which impose electrical and thermal limits on device operation and result in demanding manufacturing tolerances. The state of the art for such devices at mid W-band frequencies (near 94 GHz) is approximately 100 W output power with an electron beam current of 100-250 mA and a beam voltage of 20-25 kV. In comparison, for practical applications in W-band, the Navy desires TWTs producing much greater power (5X nominally) and wide bandwidth. Such TWTs do not currently exist in acceptable form factors.

The fundamental enabling technology for such a TWT is the electron beam generation, focusing, and transport system. The formation of the electron beam, in terms of focusing, transport, and current density, ultimately determines the output power and instantaneous bandwidth of a TWT. While higher beam current allows more RF power to be generated in the amplifier circuit, a high magnetic field is required to confine and transport such a beam through the small beam tunnel transiting the circuit. In the present state of the art, the magnet required to generate the high quality and very intense magnetic field needed to confine such a beam is large and heavy. For example, at W-band a conventional magnet (either electromagnet or permanent magnet) used for high-current beams (> 500 mA) of appropriately tight focus typically weighs 50-100 pounds. Lower-current beams can be focused by more compact configurations, such as conventional periodic permanent magnets (PPM), but these TWTs produce significantly less RF power than required. Spatially-distributed beams, such as sheet beams, are effective at producing high device power density (electron beam power per device weight). However, at high frequencies, these devices are prone to beam-defocusing instabilities and parasitic RF oscillations due to limited fabrication precision that causes non-uniformities in the magnetic field and RF circuit. Therefore, compact electron beam generation, focusing, and transport systems suitable for high power W-band TWTs are a critical enabling technology for future millimeter wave systems.

The Navy needs a novel electron beam focusing system for generation and transport of high-power (10 kW peak) electron beams of round cross-section. Ultimately, the electron beam focusing system will be integrated with a broadband beam-wave interaction circuit and an electron beam collector to form a complete W-band TWT. Development of the complete TWT is beyond the scope of this effort and details

## VERSION 8

of the intended interaction circuit need not be specified as multiple device concepts require this technology.

To achieve the required beam current while minimizing the overall volume and weight (including the size and weight of any power supplies necessary to operate the device), a solution utilizing PPM based focusing and precision fabrication methods is anticipated. The design (including the integral electron gun), the fabrication techniques for the magnet structure, the magnetic materials, and the methods for integration of the magnets with appropriate RF circuits should result in designs that produce higher transport magnetic fields for a given magnet volume than is possible with conventional PPM based focusing. Magnetic materials should be capable of stable operation at temperatures up to 200°C. The magnetic focusing system should maintain the transverse dimensions of the electron beam over the entire beam transport distance of 5 cm for 100% beam transport (no RF applied) and consistent with efficient beam-wave interaction at W-band. However, no RF circuit is required of this effort and the technology shall be demonstrated as a beam-stick (i.e., with a copper “blank” containing only the beam tunnel in place of the circuit). The beam-stick shall have a uniform 4 mm by 4 mm square cross-section extending along the entire 5 cm tunnel length, consistent with the expected size and shape of the envisioned W-band amplifier interaction circuit.

The electron gun shall operate at a voltage of 25 kV or less with a minimum peak beam current of 0.4 amperes and be capable of pulse repetition rates of 10-50 kHz with a minimum duty factor of no less than 3%. The round electron beam should be transported through a tunnel no larger than 0.5 mm in diameter, with a maximum average beam diameter of 0.3 mm. The pulse voltage required to turn the beam on and off is another key design consideration, as it affects the size and weight of the power supply and pulser circuit required to operate the device. Consequently, the electron gun should be designed to require the lowest possible voltage swing necessary for device operation. The electron gun should also be designed for maximum operational life.

Vacuum device performance is determined by mechanical dimensions and precision alignment of the electron beam, magnetic field, and RF circuit. Consequently, manufacturing, including yield, is the overwhelming cost driver for any vacuum device. For W-band devices, the small feature sizes and tight machining and assembly tolerances required for stable operation are extremely challenging. Therefore, advances in fabrication, machining, alignment, fixturing, and joining techniques are required to reduce the cost of manufacturing the electron beam focusing system. Consequently, designing critical components, such as the electron gun and magnet assembly, to take advantage of advanced fabrication techniques is also an important part of this effort.

Acceptable solutions must meet the mechanical and electrical requirements described above. The key goal is then to optimize the power density of the device where power density is defined as the peak beam power divided by the combined weight of the gun, beam transport system (including magnets), beam tunnel “blank”, and collector. A minimum power density of 500 W/lb is the goal of this effort. The solution should have some degree of scalability to accommodate different RF circuit lengths and widths (with proportional increases in beam focusing system size and weight).

Demonstration of a beam-stick prototype at the company facility is required to verify performance and assess power density. In order to confirm beam transmission, the collector should be isolated, though collector depression is not required. The physical interface of the electron gun should avail itself to integration with a W-band beam-wave interaction structure (circuit) according to standard industry manufacturing practice without compromise of performance or reduction in power density. Therefore, a technical data package (TDP) sufficient to facilitate replacement of the beam-stick “blank” with a future circuit, including modelling, simulation, assembly, processing, quality conformance, and test instructions, shall be delivered with the prototype to the Naval Research Laboratory at completion of the effort.

## VERSION 8

PHASE I: Develop a concept for a compact electron beam focusing system that meets the objectives stated in the Description. Demonstrate the feasibility of the proposed approach by some combination of analysis, modelling, and simulation. The feasibility analysis should confirm the compatibility of the solution for integration with an appropriate W-band traveling-wave interaction structure (circuit) and beam collector through prediction of the expected performance from a complete device. The Phase I Option, if exercised, will include the initial design specifications, initial interface description, test specification, and capabilities description to build and test a prototype beam focusing system (with beam-stick and collector) in Phase II.

PHASE II: Develop, demonstrate, and deliver a prototype compact electron beam focusing system (with collector and beam-stick) that meets the requirements in the Description. Note that this effort is iterative by nature and more than one prototype (or partial prototype) may be developed. At the conclusion of the effort, test, seal, package for vacuum integrity, and deliver to the Naval Research Laboratory the best performing prototype. Test data shall also be delivered with the prototype as well as operating instructions and the TDP as noted in the Description.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Government use. Transition will include assisting with integration of beam-wave interaction circuits and scale the beam focusing system to produce specific device designs (for example, W-band TWTs). The technology will be validated by providing fabrication, process, and test support in manufacturing and demonstrating specific devices incorporating the electron beam focusing system.

The technology resulting from this effort is anticipated to have commercial application in the telecommunications industry; for example, as amplifiers in 5G backhaul transmitters.

### REFERENCES:

1. Zhang, X., Feng, J., Cai, J., Wu, X., Du, Y., Chen, J., Li, S., and Meng, W. "Design and Experimental Study of 250-W W-band Pulsed TWT With 8-GHz Bandwidth." IEEE Transactions on Electron Devices 64 December 2017: 5151-5156.  
<https://ieeexplore.ieee.org/document/8093750>.
2. Theiss, A. J., Meadows, C. J., True, R. B. "Experimental Investigation of a Novel Circuit for Millimeter-Wave TWTs." IEEE Transactions on Electron Devices 54 May 2007: 1054-1060.  
<https://ieeexplore.ieee.org/document/4160141>.
3. Leupold, H. A. and Potenziani, E. A Permanent Magnet Circuit Design Primer. Army Research Laboratory Technical Report ARL-TR-946, July 1996, DTIC accession number ADA311457;  
<https://apps.dtic.mil/sti/citations/ADA311457>.
4. Borchard, P., Appert, S., and Hoh, J. "Fabrication of Split-Section X-band Structure Using Elastic Averaging." Journal of Physics, Conf. Series 1067, 2018: 082002.  
<https://iopscience.iop.org/article/10.1088/1742-6596/1067/8/082002>.

KEYWORDS: Traveling Wave Tube; periodic permanent magnets; PPM; PPM focusing; W-Band; Electron Beam Focusing; Power Amplifiers; Electron Gun

## VERSION 8

N221-038 TITLE: Navy Threshold Velocity Detector Redesign

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop a new threshold velocity detector that identifies two or more distinct velocities, uses little to no power, and reduces corrosion potential compared to the legacy device.

**DESCRIPTION:** The current threshold velocity detector system is manufactured primarily from aluminum and a custom rubber to allow for operation. This system experiences corrosion due to the direct interface with a sea-water environment and the mechanical design. This incurs a significant rework and life cycle cost. Some areas for improvement for the current system that could increase the performance and maintainability include:

1. Increase corrosion mitigation: The current system experiences corrosion of the mechanical parts as well as breakdown of the rubber compound over time due to interface with the seawater environment. This could be improved upon by integration of new non-interfacing technologies or new streamlined designs that reduced the parts that interface with the environment.
2. Integration of new technologies: The current system is a mechanical switch and due to the force/velocity being measured it can act temperamentally and the direct interface with the environment has led to issues with corrosion as previously mentioned.
3. Reduction in life cycle costs: This could be achieved by installing a Commercial off the Shelf (COTS) item with some modification or at least making the repair of the system easily performed. The current system requires an intensive rework and repair if malfunctioning that costs significant time and money to accomplish.
4. Ease of testing outside environment: This system has trouble with consistent testing and the new design would require a more reliable and repeatable testing mechanism to ensure proper function out of the environment before the use of the system.

Prototypes will be tested by the contractor and the Navy to meet the requirements of the detector and the program safety requirements.

Replacement of the current inventory of the legacy detectors will also be considered as the program is expected to remain in-service for at least 30 more years. This system could also be used to increase the information in future systems fed into the program and allow for better understanding of the current designs. This will provide opportunities for a lower cost design/simpler design that will relate to a smaller failure pool at the maintenance facilities and reduced downtime for current assets. Preventing corrosion will reduce the costs associated with rework and repairs during these maintenance actions.

The current leading technologies in the velocity detector industry include Coriolis, Differential Pressure, Magnetic, Multiphase, Turbine, Ultrasonic, and Flow velocity detectors. As this situation would support sea-water applications, gas measuring devices such as Vortex and differential pressure meters would

## VERSION 8

likely not fit the application. There are other options in the industry and while these are the leaders in technology, other velocity detectors will be considered. Even using the backbone of a COTS unit, it will require significant R&D effort in order to successfully fulfill this 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), formerly the Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

**PHASE I:** Develop a concept for a threshold velocity detector, which will be considered for feasibility of manufacturing and ease of installation into the current operation. Design approaches will be developed that will allow all requirements to be met and discussed with the Government. Technology improvements and risk reduction of the aluminum mechanical components to indirect or more corrosive inhibitive materials interfaces will be another focal area of this phase. Upon selecting an approach, a concept will be defined and developed into a buildable design. Analysis will be performed on the concept to determine the feasibility of the concept to meet requirements. Manufacturing processes required to manufacture a threshold velocity detector will be investigated and defined. A cost analysis will be performed to document the total life cycle cost of a new threshold velocity detector in comparison to the legacy design. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Manufacture several prototype detectors utilizing the design and manufacturing processes defined in Phase I. These prototypes will be tested to meet the requirements of the detector and the program safety requirements. The testing will be conducted by the contractor and the Navy. When Navy specific assets are required for testing, the Navy will provide the assets or conduct the test for the contractor. In the event of any test failures, conduct root cause investigations and implement corrective actions as needed. Upon successful validation of the prototypes, the prototypes will be delivered to the Government for the completion of program integration testing and in-water testing.

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

**PHASE III DUAL USE APPLICATIONS:** Support the Navy in transitioning the threshold velocity detector to Navy use through system integration and qualification testing. Upon completion of a successful Phase II and program integration testing, finalize the design and manufacturing processes into final production drawings that are representative of the end item as tested. Production drawings will be provided to the Government. Document and provide to the Government assembly & disassembly procedures, inspection procedures, maintenance procedures, and repair procedures that will be used to support threshold velocity detectors for the duration of their service life. Once this new detector design is qualified and determined to have cost benefits, and/or performance improvement the new detector will be cut into production. Replacement of the current inventory of the legacy detectors will also be considered as the program is expected to remain in-service for at least 30 more years. Commercial application of this technology can be in any system where a threshold velocity is required to initiate a safety intervention or sequential operation.

## VERSION 8

### REFERENCES:

1. "C-8\N-IND\CH-5-1 Flow." IDC-Online.com. 2021-02-09, [https://www.idc-online.com/technical\\_references/pdfs/instrumentation/Industrial\\_Instrumentation%20-%20Flow.pdf](https://www.idc-online.com/technical_references/pdfs/instrumentation/Industrial_Instrumentation%20-%20Flow.pdf).
2. Flow Measurement in Open Channels and Closed Conduits. NBS Special Publication. U.S. Department of Commerce, 1981-10-01. <https://www.govinfo.gov/content/pkg/GOVPUB-C13-c0f8a094b9fcc5c32be685edbd48f942/pdf/GOVPUB-C13-c0f8a094b9fcc5c32be685edbd48f942.pdf>.
3. Nisancioglu, Kemal. Corrosion and Protection of Aluminum Alloys in Seawater. Norwegian University of Science and Technology. Trondheim, Norway. <https://www.osti.gov/etdeweb/servlets/purl/20671863>.

KEYWORDS: Threshold velocity detector; corrosion mitigation; environment; seawater corrosion inhibition; repeatable; underwater body; life cycle cost

## VERSION 8

N221-039 TITLE: Flexible Unmanned Vehicle Stowage System

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a flexible, common stowage system for Unmanned Undersea Vehicles (UUVs) onboard surface ships.

DESCRIPTION: Current UUVs are provided with their own stowage and handling cradles, which require unique stowage space, material handling equipment and slings, and tie downs for securing to decks and bulkheads. There is no dedicated, common handling and stowage system for small or medium UUVs. A common, flexible handling and stowage system, that can accommodate different UUV configurations, can optimize the use of shipboard space, minimize development costs, and standardize operations. In Navy Large Unmanned Surface and Undersea Vehicles: In “Navy Seeking New Technology For Unmanned Boats, Subs,” an article in the October 18, 2019 National Defense Magazine [Ref 2], it was stated that Navy and DOD leaders believe that shifting to a more distributed fleet, to include Unmanned Systems, is operationally necessary, technically feasible, and affordable. No known commercial solution exists.

Unmanned vehicles of interest will generally be smaller than 20 feet in length, less than 2 feet in diameter and less than 2500 pounds. Available space reservations where the UUV stowage system might reside on LPD 17 Class should be constrained to upper vehicle deck areas and other locations accessible by ships elevator transport.

Stowage system must be capable of being prototyped for use with small and medium UUVs. System must be capable of meeting shipboard stowage requirements (sea state, tie downs, etc.) and interface with existing auxiliary systems which perform launch, recovery, refueling, recharging, rearming, and limited maintenance and repair.

The prototype will first be evaluated on land at the company’s facility to determine the system’s capability to meet performance goals defined in the Phase II Statement of Work (SOW). If Phase II testing is deemed successful, the project will move to at-sea testing on-board an LPD 17 Class ship. The at-sea testing will consist of maneuvering a UxV from the well deck area into stowage, securing for sea, and then unloading and maneuvering back to the well deck area.

PHASE I: Define and develop a concept for flexible stowage for Unmanned Systems that can be utilized on an LPD 17 Class of ship. Demonstrate feasibility of design through modelling and draft concept of operations. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I efforts and the Phase II Statement of Work (SOW), develop and deliver a prototype flexible handling and stowage system for UUVs for use on LPD 17 Class of ship. The prototype will first be evaluated on land at the company’s facility to determine the system’s capability to meet performance goals defined in the Phase II SOW. If Phase II testing is deemed successful, the project will move to at-sea testing on-board an LPD 17 Class of ship. The at-sea testing will consist of maneuvering a UUV from the well deck area into stowage, securing for sea, and then unloading and maneuvering back to the well deck area.

PHASE III DUAL USE APPLICATIONS: Upon successful completion of Phase II, support the Navy in transitioning the technology to Navy use to include test and validation in accordance with Navy regulations and requirements. Following testing and validation, the end design is expected to first be

## VERSION 8

deployed on the LPD 17 Class of ship, and capable of being utilized across all Navy amphibious platforms. Larger scale commercial operations utilizing UUVs of this scale may benefit from the system.

### REFERENCES:

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

KEYWORDS: Unmanned Maritime Vehicle Systems; Unmanned Undersea Vehicle (UUV); Unmanned Vehicle Stowage; Common UxV Stowage; Modular Stowage; Flexible Stowage.



## VERSION 8

N221-040 TITLE: Shipboard Advanced Metal Manufacturing Machine

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a shipboard, advanced metal manufacturing system for Navy expeditionary environments with a closed-loop feedback system adaptable to operational conditions.

DESCRIPTION: Currently, Additive Manufacturing (AM) equipment suitable for afloat use is limited. The current capabilities were installed to support the development integration requirements for AM equipment, but is currently only limited to polymer machines. Current metal AM technologies are designed for the lab or machinery spaces shoreside, and have not been configured for the harsh shipboard environment. The inclusion of a metal AM capability shipboard would drastically improve ship self-sufficiency and increase readiness. There are increased needs for AM afloat as it is explicitly identified in the COMNAVSEA Campaign Plan 3.0 as a technology focus area. This SBIR topic directly supports efforts to integrate AM into the Fleet and support a more self-sufficient ship. In addition, the Design for Maintaining Maritime Superiority 2.0 requires that the Navy maximize its use of AM to fabricate “hard to source” or obsolete parts, reduce cost, field more effective systems, and reduce reliance on vulnerable supply chains through production at the point of need. Current metal AM technology can be classified under powder bed fusion (PBF), direction energy deposition, material extrusion, sheet lamination, or hybrid processes. These processes all have their benefits and limitations from a part production standpoint. At this time, these metal AM system installations are typically expected to be on the shop floor in industrial or lab settings. There is an interest to integrate these metal AM systems in more expeditionary settings to increase warfighter readiness and increase the Navy's distributed manufacturing capabilities and self-sufficiency. The operational conditions within these expeditionary settings include ship motion, ship vibration, shock, ventilation, and electromagnetic interference (EMI). In order to successfully install metal AM equipment and enable adequate operation of the equipment, the machine must not experience severe degraded performance under these conditions. Testing of these conditions in the lab environment should occur to determine system performance under shipboard environmental conditions. These tests should be comparable to the MIL-STDs mentioned below. The Navy is seeking a system that has optimized tool pathing and programming built-in, is able to additively build parts, and is capable of subtractive finishing said parts, all within the same unit. The machine must be able to be disassembled, to become a hatch able unit, and be able to additively manufacture as well as subtractive cut hard alloys, such as high carbon and stainless steels. The system must have a built-in sensor package to be able to monitor aforementioned operational conditions, perform in-situ monitoring of each build to inform part certification, and establish a report for each build capturing all the processed sensor data, print parameter information, and AM equipment health data. In addition, part removal is generally a post-printing machining event that uses specialized equipment, generally not available shipboard. This unit must demonstrate ease of part removal from the build plate. The solution should also have modular and scalable configurations to enable manufacturing of large parts, on the order of 5ft x 5ft x 5ft, and small parts, around 5 in x 5 in x 5 in. The design must address effects the expeditionary environment may have on the machine so that it can operate while deployed. The design must be able to perform at the same performance standard as current hybrid AM equipment on the market as it pertains to geometric complexity for laser DED manufacturing processes.

This SBIR topic will address the current shipboard mitigation requirements associated with shipboard integration and performance of metal AM. The product developed from this topic could result in the establishment of a Navy vendor for shipboard AM equipment. In addition, the current modifications, costs, and qualification to Commercial Off the Shelf (COTS) equipment would no longer be required if the system was designed around the shipboard environment. Additive manufacturing has the potential for

## VERSION 8

major readiness impacts for the Fleet, improving self-sufficiency and reducing the reliance on the supply chain.

The product will be assessed against the MIL-STDs listed below:

1. MIL-S-901D, Amended with Interim Change #2, Shock Test, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for
2. MIL-STD-167-1, Mechanical Vibration for Shipboard Equipment (Type I - Environmental and Type II - Internally Excited)
3. MIL-STD-461F, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
4. MIL-STD-740-2, Structure-borne Vibration Acceleration Measurements and Acceptance Criteria of Shipboard Equipment

**PHASE I:** Develop a conceptual design of a modular, advanced metal manufacturing unit that can additively fabricate and subtractive machine different alloys, including, but not limited to high/low carbon steels, stainless steels, titanium, and various aluminum series as described in the Description. Show feasibility through analysis, modelling, simulation, and testing. Additionally, consideration to the on-board sensor packages should be identified to support in-situ monitoring of the build process, responsive feedback loops based on print conditions and monitoring, as well as operational envelope awareness to provide corrective action during a build when necessary. Finally, the logistics support trail required to sustain the technology should be identified as part of the conceptual design. Special considerations to consumables, HAMZMAT concerns, maintenance processes, and ancillary equipment requirements should be provided. Provide concepts for safety and equipment environmental (noise, structural vibration, heat output, habitability, etc.) management protocols to ensure safe operation of the sailors during general quarters and equipment operation.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Build and deliver a prototype advanced metal manufacturing system optimized for Navy expeditionary environments. The prototype should be characterized using environmental shipboard testing standards as a guide such as vibration (MIL-STD 167), shock (MIL-STD 901), and EMI (MIL-STD 461), and static angle testing. The prototype should demonstrate the ability to additively build the part and subtractive finish the part all within the same unit. The included sensor package should perform in-situ monitoring of each build to inform part certification and establish a report for each build capturing all the processed sensor data, print parameter information, and AM equipment machinery health data. Logistics support requirements, operations and maintenance manual, training, and installation/facility requirements must be provided. The equipment will be installed at a stateside Navy research and development location to be determined.

**PHASE III DUAL USE APPLICATIONS:** Develop production ready advanced metal manufacturing system optimized for Navy expeditionary environments in at least the smallest and largest configurations as mentioned in the Description. The equipment must be able to operate in the shipboard environment (machine shop or welding spaces) and be able to additively build the part and subtractive finish the part all within the same unit. The unit must meet all requirements stated within the Description. Shipboard installation guide, operations manual, maintenance manual, training, and logistics supply support packages must be included with the unit(s). This machine should have operational conditions established and tracking of the operational conditions to facilitate at-sea printing part certification. A sensor suite must be included to perform in-situ monitoring of the builds, environmental assessment of the ship space conditions (motion/vibration) to inform operation envelope fabrication restrictions, and a "health assessment" of the printed part. Considerations should be given for reducing the logistics footprint required to support the unit and minimize the reliance on the supply chain.

## VERSION 8

The results of this SBIR topic will transition to the NAVSEA AM program and will be installed in a shipboard advanced manufacturing lab. It will develop technical authority guidance for qualification and certification in the afloat environment. A Phase III will focus on additional capabilities and acquisition of the system for installation on additional ships under the afloat AM program of record. Commercial applicability of this system could be found in the offshore drilling industry and commercial shipping industry.

### REFERENCES:

1. Zi-jue, Tang et. Al, A Review on in situ monitoring technology for directed energy deposition of metals, “The International Journal of Advanced Manufacturing Technology (2020)”, Vol 108, 3437-3463, 2020
2. Everton, Sarah K. et al, Review of in-situ process monitoring and in-situ metrology for metal additive manufacturing, “Materials and Design”, Vol 95, 431-445, 2016
3. DebRoy, T et al, Additive manufacturing of metallic components—Process, structure and properties, “Progress in Materials Science”, Vol 92, 112-224, 2018
4. Donghong, Ding et al, Wire-feed additive manufacturing of metal components: technologies, developments and future interests, “International Journal of Advanced Manufacturing Technologies”, Vol 81, 465-481, 2015

**KEYWORDS:** Additive metal manufacturing; 3D printing; shipboard Additive Manufacturing; optimized tool-pathing and programming; self-sufficient metal manufacture.

## VERSION 8

N221-041 TITLE: Compact High Power Mid-Wave Infrared Laser System

OUSD (R&E) MODERNIZATION PRIORITY: Directed Energy (DE)

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 the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a compact high power laser system that provides broad spectral coverage across both atmospheric transmission windows in the mid-wave infrared band.

DESCRIPTION: Infrared (IR) passive sensors, essentially IR cameras, have been widely used for intelligence, surveillance, reconnaissance, and tracking (ISRT) and are increasingly being deployed for targeting. For both purposes, the mid-wave infrared (MWIR) band is particularly attractive for conditions of poor visibility and for nighttime use. These sensors vary in sophistication but use arrays of photodetectors that are generally sensitive to IR radiation across a wide wavelength band. For high resolution ISRT applications, the detectors are large two-dimensional focal plane arrays (FPAs) with pixel counts in the millions. Driven by energetic research in the area, IR FPA format, efficiency, noise performance, and spectral sensitivity are steadily improving. Targeting sensors may not require such large format detectors but nonetheless benefit from the drive to produce ever larger, more sensitive, and more efficient IR FPAs at lower costs. In either case, the result is the proliferation of increasingly sophisticated, completely passive imaging sensors that can cover the entire MWIR band with high resolution, yet require little electrical power and are, overall, increasingly compact, and affordable.

Comparable active IR systems, whether active imaging sensors, range finders, illuminators, beacons, or robust countermeasures, are not so fortunate. Active IR systems – at least those exhibiting the most basic level of sophistication, require IR lasers as sources. Lasers, whether gas lasers, chemical dye lasers, or solid state lasers, emit radiation at very specific and stable wavelengths. This is one of their chief strengths. For some applications however, this is their chief drawback. Building an active IR laser source that emits across a wide band (a set of multiple discrete wavelengths) is difficult, typically requiring a separate laser for every wavelength desired within the band. True wavelength agility – that is, selecting individual wavelengths “on the fly” or by system presets is expensive because it typically requires complex tuning mechanisms or includes multiple individual lasers that are simply turned off when not needed. For example, a laser illuminator in which individual systems are programmed to emit at certain sub-bands so as to be distinguished from (or not interfere with) other such systems is inherently complex, heavy, and costly, especially if the emitted power is significant. Semiconductor lasers offer some relief since they are inherently compact. However, to achieve appreciable power levels and broad spectral coverage, multiple semiconductor laser diodes must be combined.

Complicating matters, the MWIR spectrum is divided into two main sub-bands separated by a region of virtually complete atmospheric absorption. Even within the sub-bands, atmospheric transmission is still highly variable with changes in absorption occurring with both season and latitude. Passive imaging sensors are not greatly handicapped by this fragmented spectrum of usable wavelengths because they still “see” across all the wavelengths that are transmitted and benefit from time integration of the received IR

## VERSION 8

power. However, MWIR lasers, if unfortunate enough to be chosen at the wrong wavelength, simply waste their power trying to burn through atmosphere that is largely opaque to them. Consequently, active MWIR systems must be carefully designed at properly chosen wavelengths spanning the MWIR spectrum (or at least the portions of the spectrum of interest) in order to assure availability of operation. Multiple individual lasers are therefore an unavoidable consequence of agile active MWIR systems.

Multi-laser systems suffer from one additional constraint. To be tactically useful, they should emit a high-quality beam from a single aperture. Good beam quality (near diffraction limited) also provides for optimal system optics and beam propagation and therefore makes maximum use of the available system power. A single, well-formed beam at the output aperture simplifies the beam director, both mechanically and optically, reducing overall system size, weight, power, and cost (SWaP-C). System SWaP-C is often the overriding consideration in how widely a tactical system will be deployed.

The Navy needs a compact, high quality, broad-spectral laser source in the MWIR band. In this context, “laser source” is understood to mean an integrated assembly of individual lasers and beam combining optics. The laser source should cover both MWIR atmospheric sub-bands, nominally 3.5-4.1 microns and 4.6-4.9 microns, with a combined output optical power of 100 W minimum in continuous wave (CW) operation. Alternately, quasi-CW operation is allowable where the laser source is pulsed at a minimum of 100 kHz and a sufficiently high duty factor to achieve 100 W of average power output. The output power may be weighted toward either sub-band but each sub-band must include at least 30% of the total emitted power. Coverage of the sub-band is defined as at least three (more is preferred) discrete spectral lines across each sub-band (while taking into account the objective of maximizing atmospheric propagation). More lines may be chosen so as to spread the power more evenly across the sub-bands or to decrease the power required from each individual laser.

It should be noted that a scalable solution in which spectral lines can be added to future versions of the laser source is highly desirable. Spectral lines should be chosen for maximum atmospheric transmission in a tropical maritime environment as defined by MODTRAN® or an equivalent atmospheric propagation code evaluated for 10 km range at sea-level.

The laser source should have a single output aperture and emit a near-diffraction limited beam with a minimum M2 factor of 2.0 and a goal of 1.5 (M2 is herein defined according to ISO Standard 11146). In order to facilitate the safe testing of prototypes at low average power, the laser source shall include an interface for pulse operation at continuously variable pulse widths (starting from a 5  $\mu$ s minimum pulse width) and arbitrary duty factor. Note that, in pulse operation, the entire source (even if a quasi-CW solution is pursued) is intended for pulse operation as a unit, not individual laser lines separately. The laser source may be liquid cooled but note that the volume of cooling hardware (connectors, manifolds, cold plates) present in the source is included in the size goal for the unit. Chillers, heat exchangers, pumps and other cooling hardware required to supply the liquid coolant is considered external to the laser source and does not factor into the size and power budget calculations. Likewise, power supplies and power conditioning units are considered external to the laser source. The laser source has a desired minimum wall plug efficiency (WPE) of 10% where WPE is defined as the total CW (or quasi-CW) optical output power divided by the total electrical power provided to the source from the external power supplies. The laser source should not exceed three cubic feet in volume and gimbals, beam steering, and stabilization systems are not included as part of this effort. Testing will be done by the company in a laboratory environment.

Life-cycle cost is always a fundamental concern and the laser source should therefore be designed with affordable manufacturing, long-term reliability, and ease of use (including maintenance) in mind. Acceptable solutions are therefore assumed to incorporate solid state or semiconductor lasers and multiple-laser solutions should take into account the manufacturing cost associated with the beam

## VERSION 8

combiner and the cost implications associated with a scalable architecture (scalable in spectral content and by extension, total power). However, any solution that meets the requirements (including solutions that employ single lasers as sources) is acceptable and, while the goal of this effort is not to produce manufacturing technology, the production cost of the laser source should be estimated and the key manufacturing steps and processes that are identified as cost drivers should be analyzed and prioritized for remediation under a follow-on effort with a goal of \$200K as the per-unit production price.

PHASE I: Propose a concept for a compact high power MWIR laser source that meets the objectives stated in the Description. Define the laser source architecture and demonstrate the feasibility of the concept in meeting the Navy need. Feasibility shall be demonstrated by a combination of analysis, modelling, and simulation. Identify key manufacturing steps and processes and estimate the cost of the laser source in low-rate production (10 units per month). The cost estimate for the concept shall be based on an analysis of key manufacturing steps and processes, their maturity and availability within the industry, the cost and availability of key components, and by comparison to the manufacture of similar items. The Phase I Option, if exercised, will include the laser source specification, test specifications, interface requirements, and capabilities description necessary to build and evaluate a prototype in Phase II.

PHASE II: Develop, demonstrate, and deliver a prototype compact high power MWIR laser source (the laser source plus chiller and the required power supply, pulse drive, and control electronics) based on the concept, analysis, architecture, and specifications resulting from Phase I. Demonstration of the laser source shall be accomplished through production and test of a prototype (or multiple prototypes) in a laboratory environment. The analysis of key manufacturing steps and processes identified in Phase I shall be refined and updated to reflect lessons learned in fabrication and test of the final prototype. The cost estimate for low rate production shall likewise be updated. Multiple prototypes (or partial prototypes) may be produced during execution of this Phase II as the design process is assumed to be necessarily iterative in nature. However, at the conclusion of Phase II, the final (best performing) prototype laser source system demonstrator shall be delivered to the Naval Research Laboratory along with complete test data, the final manufacturing analysis, and final low-rate production cost estimate.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Government use. Identify specific manufacturing steps and processes that require maturation, mature those steps and processes, establish a hardware configuration baseline, produce production level documentation, and transition the laser source into production. Assist the Government in integration of the laser source into next higher assemblies and deployable systems.

The technology resulting from this effort is anticipated to have broad military application. Law enforcement, commercial, and scientific applications include use as sources for laser spectroscopy for chemical detection and identification (detection of explosive compounds, for example).

### REFERENCES:

1. Mecherle, G. Stephen. "Laser Diode Combining for Free Space Optical Communication." Proceedings of the SPIE 0616 15 May 1986: 281-291.  
<http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1241781>.
2. Fan, T. Y. "Laser Beam Combining for High-Power, High-Radiance Sources." IEEE Journal of Selective Topics in Quantum Electronics 11 May-June 2005: 567-577.  
<http://ieeexplore.ieee.org/document/1516122/>.
3. Pauli, M. et al, "Power Scaling and System Improvements to Increase Practicality of QCL-Based Laser Systems", Proceedings of the SPIE 10926 27 June 2019.  
<https://doi.org/10.1117/12.2508710>.

## VERSION 8

4. Sanchez-Rubio, A. et al. "Wavelength Beam Combining for Power and Brightness Scaling of Laser Systems." Lincoln Laboratory Journal 20 2 2014; 52-66.  
[https://www.ll.mit.edu/sites/default/files/page/doc/2018-05/20\\_2\\_3\\_Sanchez.pdf](https://www.ll.mit.edu/sites/default/files/page/doc/2018-05/20_2_3_Sanchez.pdf).

KEYWORDS: mid-wave infrared; MWIR Lasers; Laser Source; Semiconductor Lasers; Beam Combining; Wavelength Agility; Atmospheric Transmission

## VERSION 8

N221-042 TITLE: Advanced Piezoelectric Materials in Maritime Surveillance Systems

OUSD (R&E) MODERNIZATION PRIORITY: Microelectronics

TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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:** Integrate recent advances of piezoelectric materials with increased sensitivity and investigate innovative new sensor designs for robust deep water passive sensors.

**DESCRIPTION:** The current passive acoustic sensors used in Maritime Surveillance arrays are based on conventional piezoelectric materials. The current sensors employed in arrays include omni-directional hydrophones and multi-axis vector sensors. These are strung together similar to towed arrays used by the submarine fleet but are slightly larger in size. The Navy wants to enhance the current sensors with the latest developments of advanced piezoelectric materials and investigate innovative sensor designs enabled by these new piezoelectric materials, to provide enhanced sensitivity and lower noise floor in an equivalent, or smaller, size package. Any new sensor designs must maintain resiliency to extreme hydrostatic pressures (full ocean depth is an objective) and low deep ocean temperatures (nominally 3° C), across a range of frequencies; robustness to deployment shock (lightweight equivalent within MIL-S-901) and accelerations (on the order of 100g as would be experienced during deployment, and the transportation vibration requirements as per MIL-STD-167); and robustness to temperature shock from 100°F to 0°F. An end-to-end solution utilizing innovative packaging methodologies to reduce overall sensor form factor to facilitate array deployment in conjunction with the advanced sensors is a significant part of this SBIR research and development effort. The enhancement in sensitivity (> 8 dB re VRMS/μPa) and reduction in low frequency noise floor (> 5 dB re μPa/vHz) are primary components of this effort. These benefits will enable greater detection ranges and greater areas of sensing coverage, which can reduce operating hours on deployment handling equipment and provide a timely modernization of fixed sensor systems used within the U.S. Navy. The ultimate design will be measured against the existing family of acoustic sensors utilized across the Maritime Surveillance portfolio. The measurements will include acoustic calibration at a certified Navy test facility; the environmental robustness would be evaluated at a qualified test facility with the ability to evaluate against the requirements mentioned above: temperature, shock, and vibration.

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



## VERSION 8

PHASE I: Provide a concept and demonstrate its feasibility to achieve the Navy's goals. The primary objective is to develop a concept for a passive acoustic sensor that meets the requirements outlined in the description. The design will include details of the acoustic sensing mechanism and associated pre-amplifier network (if required). The feasibility of the design will be established through modeling and simulation. The Phase I Option, if exercised, will include the specifications, and anticipated (i.e., modeled) performance characteristics to build the prototype in Phase II.

PHASE II: Develop and deliver a prototype system(s) for testing and evaluation based on the results of Phase I. The evaluation and testing of the prototypes will be based on the requirements stated in the maritime surveillance performance specification, which includes contractor's low-level subassembly performance tests. This maritime surveillance performance specification will be provided to Phase II awardee. Evaluations and testing will include acoustic evaluation, both under ambient conditions and under hydrostatic and temperature stresses. As such, a total of 10 prototypes will be provided as deliverables. Initial testing will be the responsibility of the executing company, while follow-on testing will be the responsibility of the Navy, with the company's assistance.

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. Provide engineering support for full environmental testing, which could include low temperature thermal dwell testing, lightweight shock testing, vibration analysis, and additional acoustic evaluation testing. There is potential for some of this testing to occur in Phase II. During Phase III, a minimum of ten prototypes is anticipated to be utilized in at-sea demonstrations to assist in the full circle environmental evaluation of the design.

Some alternative Naval applications include sonobuoys, and alternative acoustic sensors residing on manned and unmanned platforms. Some commercial applications include marine mammal acoustic detection arrays and geological exploration receive arrays. This support is expected to be in the form of follow-on prototypes incorporating any lessons learned from the Phase II acoustic testing.

### REFERENCES:

1. Burdic, William S. Underwater Acoustic System Analysis. Englewood Cliffs, New Jersey: Prentice Hall, 1991; <https://asa.scitation.org/doi/abs/10.1121/1.391242>.
2. Poterala, Stephen F., et al. "Processing, texture quality, and piezoelectric properties of < 001 >C textured (1-x)Pb(Mg<sub>1/3</sub>Nb<sub>2/3</sub>)TiO<sub>3</sub> - xPbTiO<sub>3</sub> ceramics." Journal of Applied Physics 110, 014105 (2011); <https://aip.scitation.org/doi/full/10.1063/1.3603045>.
3. Messing, Gary L., et al. "Texture-engineered ceramics – Property enhancements through crystallographic tailoring." Journal of Materials Research, Volume 32, Issue 17; <https://doi.org/10.1557/jmr.2017.207>.
4. MIL-S-901(NAVY), 17 March 1989. Military Specification: Shock Tests, H.I. (High Impact) Shipboard Machinery, Equipment, and Systems, Requirements for. Available: [http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-S/MIL-S-901D\\_14581/](http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-S/MIL-S-901D_14581/).
5. MIL-STD-167-1 (SHIPS), 1 MAY 1974. Department of Defense Test Method: Mechanical Vibrations of Shipboard Equipment (Type 1 – Environmental and Type II – Internally Excited). Available: [http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-167-1\\_22419/](http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-167-1_22419/).

KEYWORDS: Piezoelectric sensors; Maritime Surveillance; Deep-water sensing; Bottom-mounted sensors; Sensor arrays; Deployed sensors

## VERSION 8

N221-043 TITLE: Enhanced Performance Radome Materials for High Speed Missiles

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 common radome architecture for multiple future missile systems which provides a significant increase in thermo-structural capability while maintaining electrical performance across wide frequency bands.

**DESCRIPTION:** Evolving weapons technology is driving advanced missiles (supersonic and hypersonic) and other flight vehicles to greater speeds and higher accelerations. Consequently, existing materials do not exist to answer the problems being caused. The result of increased speed and acceleration is higher temperatures and thermal stresses. For instance, vehicles traveling over Mach 4 reach surface temperatures of 1,500°C or higher. Rapid acceleration results in extreme thermal gradients, translating to high stresses. Flight through adverse weather such as rain or sleet, and sand and dust add additional environmental hazards which must be survived. These conditions, resulting from the evolving technologies, will require changes in materials to meet or exceed requirements to negate the effects on missile radomes. There are specific material properties, namely dielectric constant and loss tangent, which need to be low (preferably below 5 and .05 respectively). An innovative solution may consider both advanced materials and existing state-of-the-art materials. Existing materials include slip cast fused silica, oxide ceramic matrix composites, and various forms of silicon nitride. Current materials suffer inadequacies including low thermostructural robustness, excessive electrical property variation with temperature, and excessive heat conduction through the radome. Radome materials must provide for stable performance over the duration of its flight. Thermal shock is particularly difficult and can cause expansion of the outer surface during acceleration, thereby impacting both electrical performance and material structural integrity.

A critical component of future Navy missile concepts is a radome that will operate while exposed to high temperatures (~2400K) in a harsh flight environment while maintaining legacy strength and Radio Frequency (RF) transmission properties, surpassing both the capabilities of legacy radomes and current commercially available materials. It is desired that this future radome will have a common design architecture which will allow use across multiple missile types, and reduce production costs by eliminating multiple radome types. With these objectives in mind, the U.S. Navy seeks a radome design that utilizes proven materials and manufacturing methods, but also material innovations to provide increased thermal survivability while minimizing temperature-related RF performance loss.

Concepts are sought to significantly enhance the survivability of radomes while maintaining the required RF performance. Novel constructs are envisioned that build upon current state-of-the-art with material additions, substitutions, or layering. Novel new materials, or novel combinations of known appropriate materials, may be considered. It is preferred that materials with known properties be incorporated into the proposed solution to potentially reduce the time to meet the technology readiness. Proven

## VERSION 8

manufacturability and properties will be favorably considered. Advanced and novel materials could be integrated into the basic structure and/or added as additional elements or layers.

Selection and fabrication of these advanced materials to achieve novel constructs is desired. In-depth characterization and testing are critical for elucidating the mechanisms to achieve advanced survivability. Some critical considerations for any such RF radome system include electrical properties (dielectric constant, loss), thermal properties (conductivity, emissivity), structural properties across the service temperature range, and a manufacturing approach which allows for tight control of shape, size, and thickness. The awardee must propose adequate test protocols to demonstrate suitability of the proposed technology to satisfy Navy requirements. Testing can be conducted on coupons combined with modeling, or on notional prototypes. The solution must show resiliency in high temperature mechanical tests, thermal shock tests, electrical tests, non-destructive testing, and microstructural examinations.

High temperature RF property measurements of the radome materials will be needed for use in radome-level models. Tradeoffs between materials that are optimal for thermal survivability and those that are optimal for radome function will likely be encountered, requiring material development iterations. To optimize performance in all aspects, materials can be tailored in chemistry, thickness, and density.

PHASE I: Develop a concept for a common radome architecture that meets the parameters in the Description. Demonstrate that the concept can feasibly meet the requirements through analysis, modeling, and experimentation of materials of interest. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver notional full-scale prototypes (minimum of two) that demonstrate functionality under the required service conditions including thermal and mechanical stresses. Demonstrate the prototype performance through the required range of parameters given in the Description.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use in the STANDARD Missile program. Support the manufacturing of the components employing the technology developed under this topic and assist in extensive qualification testing defined by the Navy program. It is likely that the Phase III will involve classified information.

Potential commercial uses for high temperature radome performance improvements exist in the commercial spacecraft and aircraft industries and satellite communications.

### REFERENCES:

1. Kasen, Scott D. Thermal Management at Hypersonic Leading Edges. PhD Thesis, University of Virginia, 2013. <https://www2.virginia.edu/ms/research/wadley/Thesis/skasen.pdf>.
2. Walton, J.D. "Radome Engineering Handbook: Design and Principles." Marcel Dekker, Inc., New York, 1970.
3. "Predictions Of Aerodynamic Heating On Tactical Missile Domes," NSWC TR 79-21, T. F. Zien and W. C. Ragsdale, Naval Surface Weapons Center Dahlgren, Virginia 22448/Silver Spring, Maryland 20910. April 25, 1979 <https://apps.dtic.mil/dtic/tr/fulltext/u2/a073217.pdf>.

KEYWORDS: Radomes; Advanced Missiles; Thermal Shock; Radio Frequency; RF; RF Transmission; Supersonic; Hypersonic

## VERSION 8

N221-044      TITLE: Compact, High Performance Mid-Wave Infrared Sensor for Intermittent Deployment

OUSD (R&E) MODERNIZATION PRIORITY: Microelectronics

TECHNOLOGY AREA(S): Sensors

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

**OBJECTIVE:** Develop a compact and high performance mid-wave infrared (MWIR) imaging sensor for intermittent deployment on Unmanned Aerial Vehicles (UAV) in environments where attrition is expected.

**DESCRIPTION:** Infrared (IR) imaging sensors (IR cameras) are especially useful for intelligence, surveillance, reconnaissance, and tracking (ISRT) missions as well as target acquisition for weapons and fire control systems. The mid wave infrared (MWIR) band is particularly attractive for conditions of high humidity, poor visibility, and nighttime use. Highly sophisticated MWIR cameras are expensive but fully justified when deployed to high-value platforms such as surface warships and combat aircraft and where exists the near certainty that the platform will be recovered, such as with large UAVs. In these cases, not only must the MWIR imaging sensor meet extensive performance requirements (i.e., field of view, resolution, sensitivity, frame rate, slew rate, stabilization) but expectations for continuous use over long periods as well.

Not every application demands both the full range of performance and the requirement for repeated long-term operation. There are many instances when an imaging sensor of modest performance, compact size, and low cost can perform much needed, but short duration tasks. For example, a small UAV with a suitably chosen imaging sensor can be launched from virtually anywhere to “pop up” and view targets that are still over the horizon for mast-mounted sensors. Small UAVs can be sent out to closely monitor and interrogate suspect vessels, floating debris, and indented shorelines, inlets, coves, and other littoral waters hidden by barrier islands. These missions are, by nature, intermittent and of typically short duration. These missions also have a high probability of loss of the UAV due to weather conditions, enemy action, or errors made during recovery. Consequently, the imaging sensor, like the UAV, must be very affordable.

The affordability of any imaging sensor is improved by trading off performance. Native resolution – that is, pixel count of the Focal Plane Array (FPA), can be reduced if the sensor is intended to approach the target of interest. For the same reason, large aperture, long focal length, and zooming lenses are not required. Acceptable image stabilization can be achieved electronically and the sensor can be aimed by maneuvering the UAV, simplifying the sensor mount. Taken collectively, these trade-offs can greatly reduce the sensor cost. Decreasing the specifications for environmental ruggedization and operational durability normally required of military systems results in a system (sensor plus small UAV) that is highly compact, affordable, energy efficient, easily manufactured, and therefore widely deployable.

This is already the case for small UAVs fitted with cameras for amateur and commercial photography in the visible spectrum. However, comparable systems for imaging in the IR suffer from additional factors

## VERSION 8

that drive up cost substantially. IR FPAs (and especially MWIR FPAs) are comparatively expensive. In addition, to achieve acceptable imaging, MWIR FPAs must also be cooled to elevated cryogenic temperatures, most typically between 120 K and 150 K (depending on FPA material and wavelength cutoff). Consequently, the basic MWIR sensor package (not including the image processor and mounting and positioning hardware) incorporates the FPA, the read-out integrated circuit (ROIC), the optics, and the cooling hardware in a tightly integrated package. The cost is typically an order of magnitude more than for a comparable imaging sensor (comparable in format and resolution) in the visible spectrum.

Recent improvements in MWIR FPA technology have resulted in small pixel (8 micron or less) FPAs that have lower manufacturing cost. However, the use of smaller pixels requires faster (larger) optics to maintain sensitivity comparable to the larger pixel technology. So the cryo-cooler becomes the dominant cost component and the optics become the dominant weight component. However, being typically used in large, expensive, and high performance IR cameras, neither component has benefitted much from targeted research designed to reduce cost and weight.

The Navy needs a low cost, highly compact, and energy efficient MWIR imaging sensor package for intermittent, short duration missions where attrition is expected. In this context, “sensor package” is understood to include the FPA, ROIC, cryo-cooler, optics, and the enclosure that isolates the cooled components from the outside ambient temperature. The FPA must have a format of at least 1000 x 1000 pixels with small pitch (8 microns or less) and be integrated with a ROIC having the capability for high dynamic range (using variable integration time). The sensor is required to be able to focus to a blur spot of no larger than 1-2 sensor pixels in each direction. The full framerate must be at least 60 frames per second with the capability to increase the framerate to 240-1000Hz in small Regions of Interest (ROI) with addressable windowing.

Innovation is desired that fundamentally reduces the size and weight of the optical components. For the defined FPA format and pixel pitch, a 6° field of view (FOV) with conventional optics (lenses) is considered typical and is taken as the benchmark for comparison of sensor performance and Size, Weight, and Power and Cost (SWaP-C) where the power is understood to be the power required by the cryo-cooler and the FPA/ROIC pair. Solutions may incorporate gradient index optics, flat optics, microlensing, or other techniques that meet benchmark performance while reducing SWaP-C.

The integration of the FPA and ROIC with an affordable, compact, and efficient cryo-cooler is considered the key challenge in this effort. Because it has mainly been used for sophisticated, persistent systems, available cryo-cooler technology is typically specified for 10,000 to 20,000 hours of Mean Time Between Failure (MTBF). This results in greatly overpriced coolers for platforms whose total operational time will likely be less than ten hours accumulated during a handful of mission deployments. Specifically, the operational MTBF of the desired sensor package is relaxed to a value of 500 hours. The 500-hour MTBF is specified as “operational” to distinguish from the period of time that the sensor package is expected to sit unused between missions. In addition, when between missions, the sensor package must sit “cold”. That is, no power shall be required to maintain the functionality and reliability of the sensor package when not in use. The sensor package must also be cable of imaging at full performance within a minimum 120 seconds of deployment in ambient temperatures ranging from -5 °C to 45 °C. The time from deployment to operation is assumed to be determined by sensor cool-down and solutions that minimize this time are highly desirable (below 60 seconds is a goal). The attritable nature of the mission set anticipates no more than ten operational deployments before loss. However, to accommodate periodic system checks, training, and aborted missions, the sensor package should be designed to withstand 100 on-off cycles before failure with 99% confidence. Mission duration is not anticipated to exceed 60 minutes.

## VERSION 8

The benchmark for cooling is 120-150 K, consistent with HgCdTe, nbn, or Strained layer Superlattice (SLS) background-limited High Operating Temperature (HOT) FPA technology. FPAs that operate at warmer temperatures are acceptable but the solution must convincingly demonstrate that the warmer sensor package meets or exceeds the performance, size, weight, and (especially) cost of a same size, format, and pitch HOT FPA, properly cooled and operated. The sensor package must be a closed system, only requiring external electrical power and data lines for operation. The most compact and efficient solution is desired and design for depot-level repair is not needed. Solutions that require pre-mission preparation, recharging of cooling fluids, periodic field maintenance, or specialized storage conditions are unacceptable. The 1.0 megapixel FPA is defined as the minimum size of interest for the anticipated mission set. It is also chosen as a reasonable size for demonstration. The solution however should be scalable (upward) in size with proportional increases in size, weight, and power consumption. No fundamental limit should restrict the technology to the 1.0 megapixel format and the optics should allow for individual designs with different (fixed) fields of view in the range 3° to 10° (minimum). Within these limits, any cooling technology is acceptable. A final projected sensor package cost (for the 1.0 megapixel-size sensor package, including the cryo-cooler) of \$2000, when produced in quantities of 1000 or more, is the goal.

The sensor package will be demonstrated by fabrication, testing, and delivery of at least two successful prototypes. The sensor package does not include power supplies, the image processing board, static mounting hardware, or the display. However, these items must be delivered for successful demonstration of the prototype. The electrical inputs and outputs of the sensor package shall be commercially available connectors and the connectors are considered an integral part of the sensor package.

PHASE I: Propose a concept for a MWIR imaging sensor package that meets the parameters stated in the Description. Demonstrate the feasibility of the concept in meeting the Navy need through a combination of analysis, modeling, and simulation. The Phase I Option, if exercised, will include the sensor package specification, preliminary optics design, interface requirements, performance test specification, reliability test plan, and capabilities description necessary to build and evaluate a prototype solution in Phase II.

PHASE II: Develop and demonstrate a prototype MWIR imaging sensor package based on the concept and specifications resulting from Phase I. Demonstrate the prototype meets the parameters described in the Description through testing in a laboratory environment. The laboratory environment will be provided by the company. Multiple prototypes (or partial prototypes) may be produced during execution of this effort as the design process is assumed to be necessarily iterative in nature. However, at the conclusion of Phase II, two final (best performing) prototypes will be delivered, one with a 3° FOV and one with a 6° FOV, to the Naval Research Laboratory (NRL) along with complete test data and final manufacturing cost estimates. The image processing board, display, and any specialized fixturing or equipment necessary to replicate testing of the prototype sensor packages shall also be delivered to NRL.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Government use by scaling the technology to meet specific sensor program requirements and identifying specific manufacturing steps that require maturation, maturing those steps and processes, establishing a hardware configuration baseline, producing production level documentation, and transitioning the sensor package into production. Assist the Government in integration of the sensor package into next higher assemblies and deployable systems.

The technology resulting from this effort is anticipated to have applications in law enforcement, security monitoring, search and rescue, and remote imaging applications for commercial and scientific programs.

REFERENCES:

## VERSION 8

1. Gibson, Daniel, et al. "GRIN Optics for Multispectral Infrared Imaging" Proceedings of the SPIE, Infrared Technology and Applications XLI 9451 June 2015: 7 pages.  
[https://spie.org/Publications/Proceedings/Paper/10.1117/12.2177136?origin\\_id=x4323&start\\_year=2015](https://spie.org/Publications/Proceedings/Paper/10.1117/12.2177136?origin_id=x4323&start_year=2015).
2. Banerji, Sourangsu, et al. "Imaging with Flat Optics: Metalenses or Diffractive Lenses?" Optica 6 6 2019: 805-810. <https://www.osapublishing.org/optica/fulltext.cfm?uri=optica-6-6-805&id=413582>.
3. Curlier, Patrick. "Low-Cost Cryocooler Review for Intermediate Cooling Temperature" Proceedings of the SPIE, Infrared Detectors and Focal Plane Arrays IV 2746 June 1996: 7 pages.  
[https://spie.org/Publications/Proceedings/Paper/10.1117/12.243043?origin\\_id=x4323&start\\_year=1996](https://spie.org/Publications/Proceedings/Paper/10.1117/12.243043?origin_id=x4323&start_year=1996).
4. Arts, R., et al. "Miniature cryocooler developments for high operating temperatures at Thales Cryogenics" Proceedings of the SPIE, Infrared Technology and Applications XLI, 9451 May 2015: 12 pages.  
[https://spie.org/Publications/Proceedings/Paper/10.1117/12.2176323?origin\\_id=x4323&start\\_year=2015](https://spie.org/Publications/Proceedings/Paper/10.1117/12.2176323?origin_id=x4323&start_year=2015).

KEYWORDS: Imaging Sensors; MWIR Imaging; Cryo-Cooler; Focal Plane Array; Gradient Index Optics; Microlensing

## VERSION 8

N221-045 TITLE: Fiber Optic Cable for Radio Frequency Over Fiber Links

OUSD (R&E) MODERNIZATION PRIORITY: Networked C3

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 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 military fiber optic cable for analog optical communication operating at no less than 45 GHz in air and sea platform fiber optic links.

DESCRIPTION: Current military shipboard and aerospace platform communications and electronic warfare systems require ever-increasing bandwidths while simultaneously demanding reductions in space, weight, and power (SWaP). The replacement of shielded twisted pair (STP) wire and coaxial cable with earlier generation length-bandwidth product multimode optical fiber has given increased immunity to electromagnetic interference, bandwidth, and throughput, and a reduction in size and weight. To address the emerging needs of radio frequency (RF), microwave and millimeter-wave applications to route and process increasingly high-frequency signals, photonics, and fiber optics play an important role in future military shipboard and aerospace platform applications. Polarization modulation with interferometric detection and balanced intensity modulation with direct detection (IMDD) provide advantages over conventional IMDD links.

In order to realize polarization modulation and balanced IMDD photonic link technology on military platforms, polarization maintaining and multi/dual-core fiber optic cable development and qualification is required. Shipboard and aerospace optical fiber and fiber optic cable share military specifications. MIL-PRF-49291/11 [Ref 1] describes modern examples of single mode optical fiber for shipboard and aerospace application. MIL-PRF-49291/11 specifies 8.2 to 9.5  $\mu\text{m}$  mode field diameter (at 1,310 nm) and from 9.4 to 10.5  $\mu\text{m}$  mode field diameter (at 1,550 nm) single mode fiber. Two operating temperature ranges are specified (-46 to +85°C and -55 to +165°C). Maximum macro-bend attenuation at 1,550 nm is 0.03 dB for ten turns around a 30 mm diameter mandrel. MIL-PRF-49291/7D describes modern examples of single-mode optical fiber for shipboard and terrestrial applications.

MIL-PRF-85045/16 [Ref 2] and MIL-PRF-85045/31 [Ref 3] are modern examples of fiber optic cable for shipboard and aerospace application, respectively. Two cable operating temperature ranges are specified (-40 to +85°C and -55 to +165°C). Short-term minimum bend diameter is eight times the cable outer diameter and long-term minimum bend diameter is 16 times the outer diameter. The maximum cable attenuation rate for cable with 9/125  $\mu\text{m}$  single mode fiber is 1.0 dB/km at 1,310 nm, 1.0 dB/km at 1,383 nm, and 0.75 dB/km at 1,550 nm.

Shipboard and aerospace military installation requirements are well defined. No military specifications address polarization maintaining and dual-core optical fiber cable types. Innovation is needed to demonstrate military qualifiable polarization maintaining and dual-core fiber optic cables. One aspect of this research is to specify related optical fiber design and qualification test considerations relating to polarization maintaining and dual-core fibers. Another aspect of this research is to compare conventional



## VERSION 8

single-mode fiber and fiber optic cable, as specified in MIL-PRF-49291 and MIL-PRF-85045, to polarization maintaining and dual core fiber optic cables with respect to military specification and application to polarization modulation and balanced IMDD photonic links. The testing will be defined in the MII-SPEC, which is an output of proposal and early phase of effort. Testing to be done by SBIR awardee. Using data from this research effort, the Navy seeks to create new fiber and cable specifications and update MIL-STD-1678, MIL-PRF-85045, and MIL-PRF-49291.

PHASE I: Develop a concept for polarization maintaining and dual-core fiber optic cables for military and commercial applications. Demonstrate the feasibility of fiber optic cable designs, showing the path to meeting Phase II goals. Design polarization maintaining fiber optic cable prototypes that are compatible with distributed feedback laser outputs and high-speed electro-optic modulator inputs. Design dual-core fiber optic cable prototypes that are compatible with balanced photodetector inputs. Demonstrate the feasibility of the concept to meet the described parameters listed in the Description through modeling, simulation, and analysis. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype fiber optic cable design optimized from Phase I. Build the fiber optic cables to meet performance requirements described in the Description and draft specification planned for publication in MIL-PRF-85045 and MIL-PRF-49291. Test the fiber optic cables. If necessary, perform root-cause analysis and remediate fiber optic cable failures. Deliver fiber optic cables to the Navy.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use by verifying and validating the cable performance for transition to military and commercial fiber optic platforms. Commercial sector telecommunication systems, fiber optic networks, and data centers optical networks could benefit from the development of Polarization Maintaining and Dual-Core Fiber.

### REFERENCES:

1. DLA Land and Maritime. (2019, July 17). MIL-PRF-49291/11B: Fiber, optical, type II, class 5, size II, composition A, wavelength D, radiation resistant, enhanced performance characteristics (Metric). Department of Defense. [https://quicksearch.dla.mil/qsDocDetails.aspx?ident\\_number=276804](https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=276804).
2. Naval Sea Systems Command. (2014, June 17). MIL-PRF-85045/16C: Cable, fiber optic, single (one) fiber, cable configuration type 2 (OFCC), tight buffer, cable class SM and MM. Department of Defense. [https://quicksearch.dla.mil/qsDocDetails.aspx?ident\\_number=106883](https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=106883).
3. (2019, July 17). MIL-PRF-85045/31A: General specification for cable, fiber optic. Department of Defense. [https://quicksearch.dla.mil/qsDocDetails.aspx?ident\\_number=276840](https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=276840).
4. Diehl, J., Nickel, D., Hastings, A., Singley, J., McKinney, J., & Beranek, M. (2019, November). Measurements and discussion of a balanced photonic link utilizing dual-core optical fiber. In 2019 IEEE Avionic and Vehicle Fiber-Optics and Photonics Conference (pp.1–2). IEEE. <https://doi.org/10.1109/AVFOP.2019.8908161>.
5. Saitoh, K., & Matsuo, S. (2016). Multicore fiber technology. *Journal of Lightwave Technology*, 34(1), 55-66. <https://www.osapublishing.org/jlt/abstract.cfm?uri=jlt-34-1-55>.
6. Abe, Y., Shikama, K., & Asakawa, S. (2017). Multi-core fiber connector technology for low-loss physical-contact connection. *NTT Tech. Rev.*, 15(6), 1-6. <https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201706fa6.pdf&mode=show>.

KEYWORDS: Multicore Fiber; Polarization Maintaining Fiber; Fiber Optic Cable; Radio frequency; RF; Single Mode Fiber; IMDD photonic link technology

## VERSION 8

N221-046 TITLE: Velocity-Over-Ground Sensor for Inertial Navigation System Error Reduction

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy

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 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 velocity-over-ground sensor capability that accurately and covertly measures velocity relative to the ground for surface and subsurface naval platforms.

**DESCRIPTION:** Nearly all Navy platforms rely on Inertial Navigation Systems (INSs) to provide continuous position, attitude, and velocity information for accurate navigation. Without periodic external fix aiding, INS errors grow with time. However, INS errors can be controlled and reduced by employing various external position and velocity sources to bound and reduce errors. For example, use of velocity damping mechanisms can reduce velocity errors, which, when integrated, are the cause of navigation position errors. Ships systems integration enables the INS to receive Global Positioning System (GPS) updates to correct its velocity and position estimates and to detect sensor biases, but when GPS is unavailable, the system must rely on alternative sensors to maintain accuracy.

Currently, when GPS is not available, the electromagnetic log serves as this reference velocity source through the measurement, processing, and feedback of speed-through-water to the INS. Electromagnetic logs are reliable, passive, and covert, but they measure speed relative to surrounding water, rather than speed relative to the ground, and are subject to ocean currents and environmental distortions due to salinity, aeration, and temperature. The GPS, when unavailable, and electromagnetic logs are not adequate in providing velocity information for continual accurate navigation and currently there are no other solutions to fill the need. The velocity-over-ground sensor will complement, and in some cases, replace more conventional electromagnetic logs. In many operational scenarios, the velocity-over-ground sensor will enable superior navigation above and below the surface.

The Navy needs an innovative sensor that can determine velocity relative to the ground in the oceanic environment and under operating conditions typical to surface and subsurface naval vessels.

Typical conditions include:

- Operating speeds in the range of 0 to 20 knots
- Operational range/altitude from 10 to 6000 meters
- Roll/pitch changes from  $\pm 5^\circ$  to  $\pm 20^\circ$
- Sea floor type variations from sand/gravel to mud
- Water temperature in the range of  $0^\circ\text{C}$  to  $30^\circ\text{C}$

The sensor may use any signal, modeling, or processing technique so long as it maintains a long-term velocity root-mean-square accuracy in the range of 0.2 m/s to 0.7 m/s. The specified accuracy range is a function of the minimum and maximum operating and environmental conditions described in the bulleted list above. For instance, the larger velocity variance is attributed to the maximum operating range, and

## VERSION 8

vice versa. The sensor prototype may also utilize an external inertial navigation system as a co-sensor in a loose or tight coupling configuration, but target the same performance goals with size, weight, and power profile =  $0.1\text{m}^3$ , 100kg, 100W. The proposed sensor prototype will be compared with conventional sensors and evaluated based on how well it performs under the typical conditions outlined.

Absent from the list are specific covertness metrics; however, covert operations are a significant attribute to subsurface naval operations. Conventional acoustic sensors can employ covert transmissions and avoid host vehicle detection with use of high transmit frequencies which demonstrate higher seawater absorption compared to lower frequency devices. However, conventional high-frequency sensors remain limited in their range of operations, limiting use to shallow waters. In this regard, there are design considerations such as signal bandwidth, transmit power, beam width, and unique wave forms, as well as transmitted acoustic frequencies that offer a trade space in performance. Covertness considerations, such as ocean bottom bounce impacts, bottom backscatter loss, transmit side-lobes, and noise, should be incorporated in the prototype sensor concept design process. Furthermore, the sensor prototype should be able to provide an underwater vehicle with velocity-over-ground without surface expression, enabling superior navigation in operational scenarios both above and below the surface.

As noted, acoustic sensors are potential solutions to this problem, but the standard Doppler velocity log (DVL) and correlation velocity log (CVL) approaches have downsides. Projecting acoustic waves into the environment broadcasts the location of the vessel and requires many assumptions about the sea floor which may not be valid in certain instances. An ideal acoustic sensor would compensate for operating depth, roll, pitch, sea floor bathymetry, or other relevant factors by combining different operational concepts with innovative methods and models. Currently, no generic acoustic solution exists. At-sea testing will be scheduled by the Government for using an inertial navigation system comparable to the WSN-7.

This product will find its greatest use in surface and subsurface environments where GPS is unavailable or degraded, and where highly accurate positioning is necessary. While velocity-over-ground measurements have proven applicable in Remotely Operated Vehicle (ROV), Autonomous Underwater Vehicle (AUV), and towed vehicle navigation, the sensor prototype sought here supports inertial navigation correction and integration in large-scale naval platforms capable of surveying 95% of the world's ocean depths.

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

PHASE I: Develop a concept for a velocity-over-ground sensor that meets the parameters in the Description. Demonstrate its technical feasibility using analytical models, simulations, and testing. The modeling effort should consider a list of potential noise sources and characterize their potential impact on the overall measurement accuracy of a hypothetical sensor. Develop a trade space analysis to identify optimal covertness while achieving performance targets. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

## VERSION 8

PHASE II: Develop and deliver a prototype velocity-over-ground sensor based on the results of Phase I. Demonstrate the prototype meets the parameters of the Description through initial laboratory testing to confirm the design, functioning of components, and physical model underlying the theory of measurement for the sensor.

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

PHASE III DUAL USE APPLICATIONS: Assist the Navy in transitioning the velocity-over-ground sensor prototype through testing and further development to facilitate the adaptation of the technology to Navy use. The final product will be tested and verified according to the relevant military specifications for Navy use.

The technology is expected to be of use in the commercial manufacturing industry for AUVs for exploration and other sea floor uses.

### REFERENCES:

1. P. Denbigh. "Ship velocity determination by Doppler and correlation techniques." IEE Proceedings, Vol. 131, Part F, No. 3 (1984). <https://doi.org/10.1049/ip-f-1.1984.0049>.
2. M. Lanzagorta, J. Uhlmann and S. E. Venegas-Andraca. "Quantum sensing in the maritime environment/" Oceans 2015 - MTS/IEEE Washington, Washington, DC, (2015) <https://doi.org/10.23919/OCEANS.2015.7401973>.
3. S. Shady, A. Moussa, A. Sesay. "A new velocity meter based on Hall effect sensors for UAV Indoor Navigation." IEEE Sensors Journal, Vol. 19, No. 8, APRIL 15 (2009) <https://ieeexplore.ieee.org/document/8594610>.
4. T. Blanford, D. Brown, and R. Meyer. "Design considerations for a Compact Correlation Velocity Log." Proceedings of Meetings on Acoustics, Vol. 33 (2018) <https://doi.org/10.1121/2.0000928>.

KEYWORDS: Correlation Velocity Log; Electromagnetic Log; Doppler Velocity Log; GPS Challenged Environments; Inertial Navigation; Velocity-over-Ground Sensor

## VERSION 8

N221-047 TITLE: Over The Shore Messenger Line Delivery System

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Battlespace Environments

OBJECTIVE: Develop autonomous Over the Shore (OTS) refueling capabilities to make an initial connection to shore without putting manned surface craft in the surf zone. Develop a messenger line delivery system that will enable rapid and minimally manned deployment of OTS refueling hose systems.

DESCRIPTION: The first and most difficult aspect of delivering Navy fuel OTS to support Expeditionary Advanced Base Operations (EABO) is to make the connection from vessel to shore. For some new OTS systems, this is done with a messenger line using legacy line delivery methods that are complex, delay system deployment, and require additional manpower. Kinetic line firing equipment does not have sufficient range to reach from the fuel delivery vessel to shore. Deploying craft in the surf zone is manpower intensive, dangerous, and subject to surf restrictions. The currently fielded system uses craft that are large and difficult to store and maintain as capabilities to be readily available from a smaller fuel carrying vessel.

Multiple technologies exist that may safely and easily deliver the messenger line to shore, but need further development to be adapted to this specific application. The delivery system must be capable of handling the forces acting on it by the messenger line and survive the littoral environment from the vessel to shore at distances up to 2,000 feet. Some level of automation should be customized for this application to further reduce manpower requirements for system deployment. The system should not require physical human interaction after deployment and until the messenger line is received by shore side personnel or equipment and the system has confirmed that the line was received.

A successful concept will enhance OTS fuel delivery capabilities, reducing deployment time, manpower requirements and complexity while increasing personnel safety, reliability, efficiency, range, accuracy, and overall performance. The concept should demonstrate the potential to be applied to any ship or fuel carrying asset designed to provide OTS fuel delivery.

The OTS Messenger Line Delivery System must provide the required tension to pull a 6mm High Molecular Weight Polyethylene (HMPE) messenger line a minimum of 2,000 feet autonomously from ship to shore in less than 30 minutes to within a 3ft radius of a specified marked point and confirm that the messenger line has been received by shore side personnel before returning to its point of deployment. The system design may directly pull the messenger line from ship to shore or may pull a pilot line to allow shore side personnel to reel in the pilot line and tow the messenger line. A pilot line must withstand 500 lbs of tension with a safety factor of 3-5 to survive open ocean sea state 3, associated surf state conditions, currents of 2 knots, and winds up to 35 knots in a corrosive marine environment in air temperatures from -40 to 140°F and water temperatures from 29 to 95°F. The system should be fully deployable by two or fewer people. Demonstrate capability to successfully complete three consecutive deploy, deliver, return cycles with necessary maintenance performed by two or less people in 10 minutes or less between each cycle. Support the Navy's testing in a relative environment to certify and qualify the system for Navy use.

PHASE I: Develop a messenger line delivery system concept to transfer a messenger line from a host vessel to shore at distances of at least 2,000 feet, meeting the objectives stated in the Description.

The concept development effort shall consist of an analysis of alternatives for the delivery system, a breakdown of major system components, a rough order of magnitude (ROM) cost estimate for prototype

## VERSION 8

development, a detailed concept of operations (CONOPS), and a discussion of how automation will be optimized to reduce manpower requirements. Show feasibility through analysis, modelling, simulation, and testing.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II, along with identification of long lead materials.

PHASE II: Based on the results of Phase I and the Phase II SOW, develop and deliver a full-scale prototype for evaluation in a representative environment demonstrating capabilities as listed in the Description. The prototype will be evaluated to determine its capability in meeting the performance goals defined in the Phase II SOW and the Navy requirements for the OTS Messenger Line Delivery System. System performance will be demonstrated through prototype evaluation and modeling or analytical methods over the required range of parameters including numerous deployment cycles. Evaluation results will be used to refine the prototype into a mature design that will meet Navy requirements. Assess integration and risk and develop a Software Development Plan (SDP). Prepare a Phase III development plan to transition the technology to Navy use, including a cost estimate for Phase III.

The Phase II Option, if exercised, will include further testing of the prototype system deployed on a Navy vessel.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Navy use. Refine an OTS Messenger Line Delivery System for integration and evaluation to determine its manufacturability and effectiveness in an operationally relevant environment. Support the Navy for test and validation to certify and qualify the system for Navy use.

Line firing guns, the current technology used to deliver messenger lines from ship to shore, are commonly used in many industries, including utilities, fire and rescue squads, commercial fishing, shipping, and oil companies. Technology developed during this effort could potentially be introduced in any of these industries as an alternative with longer range and more capabilities than line firing guns.

### REFERENCES:

1. "Drones in T&D: Today's Benefits, Use Cases, and Best Practices for Drones in the Electric Transmission & Distribution." Measure, November 25, 2020. <https://www.measure.com/drones-in-transmission-distribution-utilities>.
2. Naval Company Inc. Bridger Line Throwing Gun. December 30, 2020. <https://www.navalcompany.com/navalproducts.htm>.
3. FREQUENTLY ASKED QUESTIONS [https://navysbir.com/n22\\_1/N221-047\\_FAQs.pdf](https://navysbir.com/n22_1/N221-047_FAQs.pdf)

KEYWORDS: Unmanned; Surf Zone; Rapid Deployment; Messenger Delivery Line; Autonomous; Fuel Delivery

## VERSION 8

N221-048 TITLE: Well Deck Securing System for Landing Craft Utility

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a maintenance-free securing system that can reliably secure Landing Craft Utility (LCU) vessels in the well deck of Navy Amphibious Class Ships in extreme sea conditions.

DESCRIPTION: Overview: L-Ships embark, transport, deploy, command, and fully support all elements of a marine expeditionary unit (MEU) of 2,000 marines, inserting forces ashore via helicopters and landing craft such as LCUs. This capability enables the Navy and Marine Corps team to accomplish a seamless transition from the sea to land to support ground forces on enemy territory by an amphibious assault.

Operation: LCUs weigh approximate 256 Long Tons when empty and 428 Long Tons when fully loaded and are transported to designated operating areas in the well decks of amphibious ships (L-ships). L-ships are capable of lowering the aft end of the ship to a depth of up to 10 ft at the stern ramp to float craft into and out of the well deck. The well deck is then pumped dry and then timber shoring and chain lashing is installed to secure the craft. The desired craft stabilization system must be able to secure the craft in robust sea state conditions. Excessive flexing of the ship can result in the legacy shoring falling loose with possible catastrophic results.

Current state: The legacy shoring system for the LCUs consists of high maintenance timber supports installed between the hull of the craft and the L-ship's well deck bulkheads and metal lashings. Each support is comprised of lengths of fire retardant timbers which are cut in place and assembled in various configurations. There are five 6" x 6" shores per side for a total of 10 per craft, or three 8" x 8" shores per side for a total of six per craft. A 8"x8" timber 15 feet long weighs approximately 215 to 250 lbs. There are then 11 lashings per side for a total of 22 per craft. The length of the timbers is determined by the location of the LCU in the well deck and must be one piece. With the difficulty to position the LCU in the exact same location every time, timbers are eventually trimmed to the extent that they become too short for most installations and need to be discarded. Cutting and installing the timbers and installing the lashings is cumbersome, a personnel hazard, and very time consuming.

Requirements: An alternate securing system that can quickly secure the craft is needed. The securing system will need to be able to secure a 482 LT LCU in a well deck in sea states up to Sea State 8. The securing system will need to be easily adjustable, simple to operate, and can stow the LCU in less than 3 hours. Concepts previously looked at include metal "timbers", air bags, tie rods, and friction mats. These concepts have been proposed but none have been prototyped on a ship.

PHASE I: Define and develop a concept for securing an LCU in the well deck that meets the requirements as stated above. Demonstrate the feasibility of the concept in meeting the Navy needs and establish that it can be developed into a useful product for the Navy. Feasibility that the LCU Securing System concept can be readily manufactured will be established by material testing and analytical modeling.

The Phase I Option, if exercised, will include the initial design specifications and a capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I effort and the Phase II Statement of Work (SOW), develop and deliver a prototype LCU Securing System. The prototype will be evaluated to determine its capability in

## VERSION 8

meeting the performance goals defined in the Phase II SOW and the Navy requirements for adjustability, simplicity, weight, and maneuverability. System performance will be demonstrated through prototype evaluation including shipboard testing and modeling or analytical methods over the required range of parameters. Evaluation results will be used to refine the prototype into a design that will meet Navy requirements. Prepare a Phase III development plan to transition the technology to Navy use.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the system to the amphibious ships with well decks. Transition opportunities for this technology include commercial ship and offshore systems that must secure heavy cargo in extreme conditions.

### REFERENCES:

1. United States Navy, COMNAVSURFLANT/ COMNAVSURFPAC Instruction 3340.3D “The Wet Well Operations Manual”, 28 Aug 17.  
<https://theboatswainmatestore.com/collections/comnavsurfpac-lant-comusfltforcom-inst/wet-well-operations-manual>.
2. United States Navy, NSTM Chapter 584, “Landing Craft and Amphibious Assault Vehicle Handling Stowage and Support Systems, S9086-TY-STM-010/CH-584R1”, 15 Mar 19.  
<https://theboatswainmatestore.com/products/s9086-ty-stm-010-nstm-584-landing-craft-and-amphibious-assault-vehicle-handling-stowage-and-support-systems-rev-4-15-mar-2019>.
3. Forest Products Laboratory 1999. Wood handbook : wood as an engineering material. General technical report FPL ; GTR-113. Madison, WI : U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: xi, [463] pages : ill. ; 28 cm.  
<https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.pdf>.
4. Northam, Jackie, Cargo Overboard, Intense Rolling: The Risks Of Fully Loaded Mega-Container Ships, NPR, International Affairs Correspondent  
<https://www.npr.org/2021/04/01/983017153/cargo-overboard-intense-rolling-the-risks-of-fully-loaded-mega-container-ships>.

KEYWORDS: Shoring; Landing Craft Utility; Well Deck; Amphibious Ships; Legacy shoring system; Lashing



## VERSION 8

N221-049 TITLE: Radar Absorbing Material Maintainability Improvements

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 innovative and durable materials to support the installation and maintenance of Radar Absorbing Material (RAM).

DESCRIPTION: The DDG 1000 class was designed for stealth operation utilizing Radar Absorbing Material (RAM). The RAM tiles currently have an environmental layer material designed to protect the tile from the elements such as Ultraviolet (UV), wind, rain, snow, etc. In-service experience has shown that the environmental layer begins to peel off at the edges within two years and if not serviced will completely peel off, thereby leaving the tile exposed to the elements, which degrades the performance of the material. The newly developed environmental layer should last three years, threshold, with an objective of a seven year lifespan. The environmental layer material is estimated to be about 60% of the total cost of the tile. Installation of current environmental layer is a depot level repair requiring trained technicians. There is nothing currently in the commercial market that meets the requirements.

Maintenance of RAM has been identified as an area of concern due to its use on topside components and specialized work requirements. Development of new materials that support crew maintenance and non-specialized installation procedures will lower life cycle maintenance costs and increase supportability of RAM. Navy desires development of novel environmental layer materials, including a glue and filler system for repair. Environmental layer should be able to be installed by a sailor with limited training and provide a 50% reduction in installation labor.

All proposed materials must be non-radar reflective and are expected to withstand temperatures of -25 to 50°C, wind gusts of 100 knots, and solar radiation of magnitude 1120 W/m<sup>2</sup> as defined in MIL-HDBK-310 and MIL-STD-810F, method 505. Prototype material will undergo performance testing to quantify radar transmissibility. Material composition will be finalized through environmental and qualification testing.

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

## VERSION 8

PHASE I: Develop prototype materials in accordance with the specifications and requirements outlined in the topic Description section. Demonstrate the feasibility of fabrication through the production of material. The Phase I effort will include plans for the prototype development of proposed technology during Phase II.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Refine and deliver prototype materials to undergo performance testing to quantify radar transmissibility. Material composition will be finalized through environmental and qualification testing in accordance with requirements. Fabrication process and installation procedures will be developed with a focus on aiding transition into Phase III. Prepare a Phase III development plan to transition the technology for Navy 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 material to DDG 1000 class destroyers. Support development of documentation including, but not limited to; technical manuals, parts lists, drawings, training guides, installation procedures, and logistics documents.

Commercial transition of this technology can be applied to aircraft, aerospace, ships, communications, and construction. Markets which focus on electromagnetic wave transmission and absorption such as cellular and communication towers would benefit from the developed materials.

### REFERENCES:

1. Gaylor, Kevin. Radar Absorbing Materials – Mechanisms and Materials. Australia: DSTO Materials Research Laboratory, 1989. <https://apps.dtic.mil/sti/citations/ADA215068>.
2. Delfini, Andrea, et al. Advanced Radar Absorbing Ceramic-Based Materials for Multifunctional Applications in Space Environment” Materials (Basel), September 2018:1730. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6165292/>.

KEYWORDS: Radar absorbing material; RAM; environmental protection of radars; radar absorption paint; marine sealant; stealth material; environmental layer

## VERSION 8

N221-050 TITLE: Advanced Cyber Threat Hunting Toolkit for Deployed Tactical Platforms

OUSD (R&E) MODERNIZATION PRIORITY: Cybersecurity

TECHNOLOGY AREA(S): Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 open architecture, modular cyber search, detection, attribution, and mitigation toolkit to directly support cyber threat hunt on tactical platforms.

**DESCRIPTION:** A necessary part of defense capabilities is the ability to detect highly advanced nation-state cyber implants and supply chain attacks within Defense systems. While evolving cyber adversary detection technologies have matured for enterprise mission and business systems, constrained tactical systems often lag behind the lifecycle of these capabilities. Unique standalone tools, supported by automation and machine-assisted decision making, are needed for deployment in austere tactical platform environments. U.S. Navy surface ship combat, weapon, navigation, and control systems are highly complex, heavily networked, and reliant upon core commercial technologies – making them susceptible to advanced cyber threats. Innovative solutions are needed to enable the search, detection, attribution, and mitigation of these advanced threats within these constrained systems.

Cyber threat hunting is reflected in current standards as a proactive search capability in specified organizational systems to detect, track, and disrupt advanced persistent threats. While emerging control system architectures support cyber hygiene and rudimentary defense and response, well-tailored cyber-attacks remain elusive to current detection technology. Reliance of next generation surface tactical platforms on technology for combat systems and navigation functions with growing concerns of cyberattacks at sea demonstrates the need for advanced tools that can be used in constrained environments.

The Navy seeks an open architecture, modular cyber search, detection, attribution, and mitigation toolkit that will be deployed as a standalone capability and scalable to work within a larger system of systems distributed platform or tiered architecture. The envisioned solution will leverage the detection and response capabilities planned for employment on U.S. Navy surface ships. It will allow for automated and semi-automated operation supported by intelligent autonomy that does not require continuous connectivity to shore-based defensive cyber operations infrastructure. When connected to shore-based or distributed maritime operations infrastructure; threat intelligence including tactics, techniques, and procedures (TTPs) and observable attribution shall be shared for attack progression tracking and proactive mitigation. Favorable consideration will be given to solutions which include advanced malware threat hunting capabilities, applicability to distributed and underway environments, and conformance to DoD and U.S. Navy requirements for cybersecurity capability deployment (DoD Instruction Number 8500.01 dated March 14, 2014 with Incorporating Change 1 Effective October 7, 2019. Subject: Cybersecurity). The solution will be tested by the Government on a representative tactical system to validate its effectiveness. Testing will include identification of gaps to target specific, custom built technologies to address those gaps.

## VERSION 8

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

PHASE I: Develop a concept for an open architecture, modular cyber search, detection, attribution, and mitigation for a cyber-threat hunting toolkit. Demonstrate the concept can feasibly meet the parameters of the Description. Show feasibility through a combination of analysis, modelling, and simulation. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop, demonstrate, and deliver a prototype toolkit based on the results of Phase I. The prototype will be tested on a representative tactical system to validate effectiveness in meeting the Description parameters. Testing will include identification of gaps to target specific, custom built technologies to address those gaps.

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

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through one or more managed acquisition activities. The prototype is a toolkit of targeted cyber threat hunter tools for niche operational technology in tactical environments, specifically U.S. Navy surface tactical platforms. Assist technology transition through developmental and operational test of the technology under cooperative and adversarial assessment conditions in an operational test environment. The technology will be matured to include a forensic capability. During product maturation, assist in conducting appropriate cyber engineering to include a security risk assessment, test and evaluation (T&E), and ensure compliance with pertinent regulatory principles and best practices (i.e., National Institute of Standards (NIST) 800 series publications, Risk Management Framework (RMF), and Cybersecurity Technical Authority (CS TA) Standards). Product may be licensed for deployment to U.S. Government users for direct use and/or licensed to a Software Support Activity (SSA) for additional integration and sustainment support.

This technology will be useful by any software company that has a need to protect their applications from cyber-attacks.

### REFERENCES:

1. Joint Task Force. "Security and Privacy Controls for Information Systems and Organizations." Gaithersburg, MD: National Institute of Standards and Technology, 2020.  
<https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r5.pdf>.
2. Jacq, Olivier, Boudvin, Xavier, Brosset, David, Kermarrec, Yvon, and Simonin, Jacques. "Detecting and Hunting Cyberthreats in a Maritime Environment: Specification and Experimentation of a Maritime Cybersecurity Operations Centre," 2018 2nd Cyber Security in Networking Conference (CSNet), Paris, 2018.  
<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8602669>.

## VERSION 8

3. Haddadpajouh, Hamed, Mohtadi, Alireza, Dehghantanaha, Ali, Karimipour, Hadis, Lin, Xiaodong, and Choo, Kim-Kwang Raymond. "A Multi-Kernel and Meta-heuristic Feature Selection Approach for IoT Malware Threat Hunting in the Edge Layer." IEEE, 2020, pp. 1-9. <https://ieeexplore.ieee.org/abstract/document/9205853>.

KEYWORDS: Cyber Threat Hunting; Tactical Platform; Advanced Cyber Threats; Detection Technology; Cyber Attacks; Advanced Persistent Threats.

## VERSION 8

N221-051      TITLE: Enhanced Performance for Fin and Control Surface Materials for High Speed Missiles

OUSD (R&E) MODERNIZATION PRIORITY: Hypersonics

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 common missile fin and control surface architecture which provides a significant increase in thermostructural capability for multiple future missile systems.

DESCRIPTION: Evolving weapons technology is driving advanced missiles (supersonic and hypersonic) and other flight vehicles to greater speeds and higher accelerations. The result of increased speed and acceleration is higher temperatures and thermal stresses. For instance, vehicles traveling over Mach 4 may reach surface temperatures of 2,100°C at their leading edges. Rapid acceleration results in extreme thermal gradients, translating to high stresses. Flight through adverse weather such as rain or sleet, and sand and dust add additional environmental hazards which must be survived. These conditions resulting from implementation of the evolving technologies will require changes in materials to meet or exceed requirements to negate the effects on missile fins and control surfaces. Current materials do not address the problems occurring. Existing solutions are based on stainless steel or nickel-based super-alloys. Temperatures experienced in hypersonic flight will exceed the structural limits of these materials. An innovative solution will consider both advanced materials and existing state-of-the-art materials. Thermal shock is particularly difficult and can cause expansion of the outer surface during acceleration, thereby impacting fin and control surface effectiveness and material structural integrity.

Critical components of future Navy missile concepts are fixed body fins and articulating control surfaces. These fins and control surfaces must withstand significant mechanical loads, extreme surface temperatures, significant temperature gradients, and avoid conducting excessive heat back into the missile body. The fixed fins may be mounted on the rocket motor, and the articulating control surfaces are mounted via an actuator shaft which is connected to an internal actuator mechanism. Thermal limits for internal components behind fins and control surfaces may be as low as 225°C. It is desired that this future fin and control surface technology have a common design architecture which will allow use across multiple missile types and reduce production costs by eliminating multiple fin types. With these objectives in mind, the U.S. Navy seeks a fin and control surface design that utilizes proven materials and manufacturing methods, but also material innovations to provide increased thermal performance while maintaining structural functions.

Notional control surface geometries are like those found on legacy Navy interceptors, which are generally approximately 9" length and span, and no more than 1" thick at the root. Lower-weight assemblies are favored. The control surfaces should be capable of withstanding panel loads of 1,500 lbf with hinge moments of 2,000 in-lb. to the actuator. Novel constructs are envisioned that build upon current state-of-the-art with material additions, substitutions, or layering. Novel new materials, or novel combinations of known appropriate materials, may be considered. It is preferred that materials with known properties be

## VERSION 8

incorporated into the proposed solution to potentially reduce the time to meet the technology readiness. Materials with smoother properties are favored. Proven manufacturability and properties will be favorably considered. Advanced and novel materials could be integrated into the basic structure and added as additional elements or layers.

Some critical considerations for any such control surface design and materials system include: (1) design optimized for both thermal and mechanical considerations; (2) high temperature chemical compatibility between multiple materials; (3) adhesion between material interfaces or layers; (4) thermal properties (conductivity, emissivity, coefficient of thermal expansion); (5) mechanical properties (strength, strain to failure); and (6) shape control in fabrication. Adequate test protocols must demonstrate suitability of the proposed technology to satisfy Navy requirements. Testing can be conducted on coupons combined with modeling, or on notional prototypes. Testing must demonstrate the proposed technology can withstand anticipated hypersonic flight conditions. While testing to MIL-STD-810 is beyond the scope of this SBIR effort, proposers may wish to consider the potential effects of all storage and flight environments on proposed materials and structures.

**PHASE I:** Develop a concept for a common fin and control surface architecture that meets the parameters in the Description. Demonstrate that the concept can feasibly meet the requirements through analysis, modeling, and experimentation of materials of interest. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Develop and deliver notional full-scale prototypes that meet the requirements in the Description. Note that this effort is iterative by nature and more than one prototype (or partial prototype) may be developed. Demonstrate functionality under the required service conditions including thermal and mechanical stresses. Demonstrate the prototype performance through the required range of parameters given in the Description. Number of prototypes tested will depend on the details of test methods chosen. Additionally, deliver two untested prototypes, test data, and remnants of tested prototypes to the Navy (NSWC Carderock Div., West Bethesda, MD).

**PHASE III DUAL USE APPLICATIONS:** Support the Navy in transitioning the technology to Navy use in the STANDARD Missile program. Support the manufacturing of the components employing the technology developed under this topic and assist in extensive qualification testing defined by the Navy program. It is likely that the Phase III work will involve classified information. While it is not a requirement for the offeror to be capable of classified work, such capability would simplify future efforts. It may also be possible for the offeror to partner with a classified-capable manufacturing firm to accomplish this step in the future work.

Potential commercial uses for high temperature performance improvements exist in the commercial spacecraft and aircraft industries and satellite communications.

### REFERENCES:

1. Kasen, Scott D. "Thermal Management at Hypersonic Leading Edges." PhD Thesis, University of Virginia, 2013. <https://www2.virginia.edu/ms/research/wadley/Thesis/skasen.pdf>.
2. Ognjanovic, Ognjen; Maksimovic, Stevan; Vidanovic, Nenad; Kastratovic, Gordana and Maksimovic, Katarina. "Structural Analyses Of Ballistic Missile Fin Configuration During Supersonic Flight Conditions." Annals of the Faculty of Engineering Hunedoara; Hunedoara, Vol. 16, Iss. 1, Feb 2018, pp. 179-182. <http://annals.fih.upt.ro/pdf-full/2018/ANNALS-2018-1-30.pdf>.
3. Ognjanovic, O.; Maksimovic, S.; Vidanovic, N.; Segan, S. and Kastratovic, G. "Numerical aerodynamic-thermal-structural analyses of missile fin configuration during supersonic flight conditions". Thermal Science, 21(6 Part B), January 2017, pp. 3037-3049.

## **VERSION 8**

<https://doi.org/10.2298/TSCI160919318O> <http://www.doiserbia.nb.rs/img/doi/0354-9836/2017/0354-98361600318O.pdf>.

KEYWORDS: Missile Fins; Control Surfaces; Advanced Missiles; Thermal Shock; Supersonic; Hypersonic



## VERSION 8

N221-052 TITLE: Low Hazard Heat Pump for Distributed Cooling

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop an affordable point-of-use water-to-water heat pump using a low hazard refrigerant or solid-state device with a small footprint, low weight, low vibration, high reliability, and low maintainability cost.

**DESCRIPTION:** Electronics are an increasingly prominent part of ship systems and weapons. The standard U.S. Navy cooling system provides 44°F chilled water throughout the ship. However, electronics equipment typically require 67°F cooling water to prevent condensation, short circuit, shock hazards, and corrosion. This (a 23°F) delta creates condensation conditions that can present an electrical hazard and accelerate corrosion. Raising the temperature of the 44°F chilled water at point-of-service (for multiple electronics cooling loads) is less efficient than lowering only for specific loads. However, raising temperature requires a heat exchanger while lowering requires a heat pump. The U.S. Navy seeks an innovative heat pump to support development of a distributed cooling architecture and topology where centralized chillers provide 67°F cooling water (instead of the 44°F chilled water). The water temperature is then reduced at point-of-service to 42-44°F (where needed) for air conditioning purposes. The net result is a more efficient cooling system onboard.

The U.S. Navy seeks heat pumps with innovative solutions to minimize environmental impact and meet volume, weight, power, noise, and refrigerant charge requirements. The global warming potential requirement limits the refrigerants used to carbon dioxide, air, water, and a short list of other compounds. Solid-state thermoelectric cooler devices or other unconventional refrigeration systems will be considered in this SBIR effort.

Operational requirements of proposed heat pumps include:

- Chilled water supply and return flow rate of 12 GPM
- Electrical power input is limited to 2 kW at 3 Phase / 450 VAC
- Total volume and weight of the system are limited to 3 ft<sup>3</sup> and 150 lbs
- Must fit down a standard Navy hatch (36 in. x 36 in.)
- Noise limit is 65 dB
- Global warming potential of the refrigerant, if used, must be less than or equal to 1
- Maintain the 42°F water outflow temperature within  $\pm 2^\circ\text{F}$  using internal controls
- User-configurable thermostat setpoints capable of turning the system ON and OFF based on external temperature and humidity sensor input
- Maximum refrigerant charge is .66 lb (0.3 kg)
- **Mean time to failure > 200,000 hours**
- Ability to operate in cooling and heating mode
- Meet relevant qualification testing including shock, vibration, electromagnetic interference (EMI), humidity, and temperature in product at end of Phase II

The proposed solutions shall be initially targeted for transition to backfit opportunities where the technology provides a solution to HVAC challenges in existing systems. Other transition targets include the Future Large Surface Combatant program DDG(X), the amphibious transport dock (LPD), and potential use in submarines.

The low Global Warming Potential (GWP) requirement in the solution will provide the ability to transition commercial and residential heat pumps away from high GWP refrigerants such as R-134a and

## VERSION 8

R-12. This addresses the California governmental push for transitioning away from high GWP refrigerants; specifically the requirement for centrifugal chillers to move away from R-134a by January 1, 2024 [Ref 1]. One of the available refrigerants in the solution is carbon dioxide. This effort will push the limit of carbon dioxide heat pump development that has seen little to no commercial or residential application in the United States. Another potential solution is solid-state thermoelectric cooling devices. The efficiency requirement of this effort will push the limits of thermoelectric device coefficient of performance to that of only cutting edge developments relating to ZT factor (main figure of merit in thermoelectric efficiency). [Ref 2].

Current platforms are not able to integrate advanced radar, electronic weapons, and lasers due to the limited capacity of the chilled water system. The Navy transition to electric drive presents issues as the chilled water demand will reach levels that are unsustainable with existing chilled water architecture designed around 44°F. Designing the shipboard distribution system for 67°F chilled water doubles the capacity of existing chillers without any size, weight or power increases, and the temperature allows for direct cooling of equipment with chilled water removing the need for cooling equipment units. The tradeoff in the removal of the cooling equipment units is the integration of the distributed heat pumps throughout the ship.

PHASE I: Develop a design for a low hazard heat pump as described in the Description. The Phase I final report shall be supported by predicted data from a subscale design of the proposed system. This subscale design must be capable of reducing a primary/internal chilled water loop from 67°F to 42°F by rejecting heat to cooling water supplied at 52°F. Proposed solution shall provide a thermodynamic analysis of the solution, estimate of the anticipated total volume and weight of the system referencing weights and volumes of individual components, documentation of estimated noise level, estimate of total refrigerant charge, evidence supporting the mean time to failure, estimate of power use, and an estimate of global warming potential of proposed refrigerant. Identify risks and mitigations, as applicable.

The Phase I Option, if exercised, will include the initial design specifications and a capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a full-scale prototype designed around 12 GPM of water flow with scaled power, weight, volume, and refrigerant charge (if applicable). Work with the Navy to develop requirements and demonstrate system performance through evaluation in a laboratory environment over the required range of agreed upon requirements. Refine the heat pump design and fabrication process to manufacture consistently in hundreds of units. Calculate a preliminary return on investment. The final product shall be designed to meet all relevant qualification testing including shock, vibration, electromagnetic interference (EMI), humidity, and temperature. Support the development of documentation including, but not limited to; technical manuals, parts lists, drawings, training guides, and logistics documents. Prepare a Phase III development plan to transition the technology for Navy and potential commercial use.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the system to large surface combatant and amphibious ships.

Transition opportunities for this technology include commercial ship and offshore systems that could benefit from efficient, low condensation cooling systems for electronics.

### REFERENCES:

1. California Air Resources Board, "Hydrofluorocarbon (HFC) Prohibition in California," 19 11 2020. [Online]. Available: <https://ww2.arb.ca.gov/resources/fact-sheets/hydrofluorocarbon-hfc-prohibitions-california>.

## **VERSION 8**

2. Attar, Alaa "Dissertation: Studying the Optimum Design of Automotive Thermoelectric Air Conditioning," Western Michigan University, 2015.  
<https://scholarworks.wmich.edu/cgi/viewcontent.cgi?article=2165&context=dissertations>.

KEYWORDS: Heat Pump; Chilled Water; Thermal; Carbon Dioxide; Thermoelectric; Thermal Management

## VERSION 8

N221-053 TITLE: Multi-Aperture Vector Sensor Vertical Array Processing Enhancements to Reduce Operator Workload

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 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 automation technology to fuse together vector sensor multi-axis direction information with high-resolution multi-aperture/multi-frequency vertical sensor beams.

DESCRIPTION: Advanced fielded surveillance systems include both sophisticated sonar arrays and processing to provide state-of-the-art real-time maritime surveillance. Over the last decade, both sensors and processing techniques have advanced considerably to keep ahead of quieting sonar contacts. Very recently, vector sensors have been developed that possess the ability to provide acoustic field directionalities at the element level. Processing techniques to fully exploit this added capability are of interest to the U.S. Navy. Additionally, advanced computing hardware has allowed sensor processing to evolve to very high directional resolutions. The existence of such high resolution creates many surfaces over which surveillance operators must manually search on many sensors individually with very minimal automation support technology.

This SBIR topic seeks to develop a technology that will both leverage new vector sensing vertical linear sonar arrays and reduce operator workload associated with the tracking and localization of sonar contacts during surveillance. Vertical linear arrays have been used for surveillance for decades and provide good vertical depression/elevation angle resolution. With the addition of vector sensor elements, improved angular resolution is possible. Proposed solutions should be capable of executing, within the framework of the Integrated Common Processor (ICP), adhering to available computational footprints, supporting single sensor processing with multiple sensing modalities such as frequency and angle, supporting multiple-sensor processing, and reducing operator workload by a factor of 6. The automated multi-aperture signal processing and data fusion required for the intended transition is highly specialized and not available commercially.

Certification of technology will require the company to collaborate with the Government's Integrated Common Processor (ICP). The integrator will be designated by the PMS-485 Program Office. Testing and certification of the software module will be performed using operational system data against relevant performance metrics. The contractor and integrator will demonstrate the capability using multiple datasets and support future changes as required by an Advanced Processing Build (APB)-like development cycle.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA), formerly the Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret

## VERSION 8

level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DCSA and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Develop an algorithmic concept to address the single- and multiple-sensor processing of vector sensor-based vertical linear arrays to simultaneously reduce sonar operator workload associated with contact tracking and localization. Demonstrate algorithmic feasibility using simulated data and realistic sonar array parameters. Provide a justification for how the proposed approach will reduce operator workload.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype by acquiring real sensor data from the Government with actual sonar array physical and processing parameters and demonstrate the ability to achieve improved contact localization and decrease sonar operator workload. Further refine the algorithm based on the findings when processing the real data. Collect and collate supporting results and provide briefings to the program office and technical points of contact.

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: Transition the software module to an appropriate surveillance system. Support the full integration, testing, and validation of the developed software module in the Government's Integrated Common Processor (ICP). The integrator will be designated by the PMS-485 Program Office. Testing and certification of the software module will be performed using operational system data against relevant performance metrics. Demonstrate the capability using multiple datasets and support future changes as required by an Advanced Processing Build (APB)-like development cycle.

In addition to the surveillance sonar benefits of the technology developed under this SBIR, many other opportunities exist for its dual use. For example, both surface sonars and submarine sonars experience similar operator workload challenges.

### REFERENCES:

1. D. Abraham, "Underwater Acoustic Signal Process: Modeling, Detection, and Estimation", Springer Nature Switzerland AG, 2019.
2. Van Trees, H. L., Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory. Wiley Print, New York, 2002.

KEYWORDS: Vector sensors; vertical linear array; multi-aperture signal processing; multi-sensor data fusion; operator workload reduction; automation.

## VERSION 8

N221-054 TITLE: Modernized Navy Fan-Coil Assembly

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop and demonstrate durable, long-life, modernized Fan-Coil Assembly (FCA), while reducing required motor horsepower, lowering noise levels, using less chilled water flow than legacy FCA units, maintaining or improving weight/volume requirements, providing greater standardization, and lowering overall life cycle as well as maintenance costs.

DESCRIPTION: Fan-Coil Assemblies (FCAs) are typically used in recirculation systems using modular design, which allows for quick and easy installations. However, FCAs on Navy ships have changed little over the last 60 years. These legacy systems are heavy, energy inefficient, and operate at a single fan speed using a V-belt-driven fan. This has the unintended consequence of causing the temperature in the supplied spaces to be either too hot or too cold, and requires the system to switch on and off intermittently during operation, thus cooling and heating the same air, and wasting energy.

This SBIR topic will seek to develop compact, light, and efficient, drive systems that can react smoothly to temperature variations. The proposed solution will develop a new series of FCAs that are efficient, acoustically compliant, aerodynamically-optimized, lightweight, and reduced size, all of which will be necessary for the next-generation Navy HVAC system. The new design will incorporate improvements that result in a reduction in the required fan motor horsepower by 30% from the legacy units per MIL-PRF-23798D, Performance Specification, Air Conditioner, Fan-Coil Assembly [Ref 1], compliance with noise levels in accordance with MIL-STD-1474D, Change Notice 1 - Change Notice 1, Noise Limits [Ref 2], and reduced chill-water flow per developing Navy requirements.

The fan shall be designed for continuous operation, have a minimum efficiency of 80 percent, and be equipped with variable speed controls meant to replace the belt-driven system on legacy FCA units. The Variable-Speed Drive (VSD) controller will be in accordance with MIL-PRF-32168, PERFORMANCE SPECIFICATION: VARIABLE SPEED DRIVE SYSTEM FOR INDUCTION AND SYNCHRONOUS [Ref 3]. The targeted water-side pressure drop is 6 lb/in<sup>2</sup> across the heat exchanger, with a maximum of 10 lb/in<sup>2</sup>. The design conditions of the entering air temperatures will be assumed to be 80°F dry bulb and 67°F wet bulb temperature, and under ambient temperatures between 40 °F and 95 °F. Design conditions for the entering chill water temperature is 43°F, supplied at 2.1-2.3 gallons per minute per cooling ton, reduced from legacy design specifications to meet new equipment performance.

The FCA shall be a complete assembly, that contains all components necessary for providing cooling and air recirculation required to satisfy compartment environmental design conditions. Each unit shall consist of a fan with a variable speed motor, a variable speed controller, air filter, thermal and acoustic insulation, a common open protocol control system, and a chilled water cooling coil. The performance of each unit will meet or exceed the performance requirements of legacy FCA units per MIL-PRF-23798D [Ref 1] and be tested to address shock, vibration, electromagnetic interference, performance testing, airborne testing, structure borne vibration testing, motor testing, and electrical power interface testing. The awardee will be responsible for the performance of all examinations and tests. The Government will reserve the right to perform any of the tests which, upon determination and capability of awardee, are deemed necessary to ensure the FCAs conform to prescribed requirements. Test plans will be developed during Phase I, with testing to take place during Phase II.

## VERSION 8

Fan-Coil HVAC systems similar to legacy Navy FCAs are commercially available, and the operating principles are well understood within the HVAC industry. However, a complete FCA system package that meets the performance requirements outlined by the existing system performance specification, MIL-PRF-23798D, while also integrating a Variable-Speed Drive (VSD) fan controller meeting MIL-PRF-32168, has yet to be realized. This topic seeks to leverage industry-developed technologies to develop a family of modernized FCAs that improve upon the legacy systems.

PHASE I: Develop an innovative concept for the next generation of naval FCAs by meeting requirements above and targeting the performance specifications for the FCA Size 25 per MIL-PRF-23798D. Evaluate the feasibility of concepts through analytical modeling. Define strategies and technologies related to cooling coil performance, optimized air-side aerodynamic performance, reduced air-borne noise, and improved component reliability. Determine the size and weight improvement expectations over existing components. Determine coefficient of performance for cooling and heating applications as well as identify water-side pressure drop and fan performance expectations. Identify risks and mitigation measures, as applicable. The Phase I Option, if exercised, will include the initial design specifications and a capabilities description to build and test a prototype solution in Phase II. This will also include the development of test plans to identify all test procedures, test facilities, sequence of test procedures, component set-up, instrumentation and data to be collected. The tests included in the Phase I test plans will be as follows:

- Motor tests
- Permeability tests
- Leakage tests
- Electrical Power Interface test
- Communication Interface
- Performance tests
- Airborne noise tests
- Electromagnetic Interference (EMI)
- Structure borne Vibrations tests
- Shock tests
- Maintainability demonstration

PHASE II: Design and deliver the prototype, full-scale, next generation Fan-Coil Assembly (FCA) Size 25 (largest size) unit (151,300 Btu/h, 3080 SCFM). Performance data shall be collected at a variety of flow rates (both air and water), air temperatures/humidity, and water temperatures. Air-borne and structure-borne noise testing shall be conducted. Validate and expand analytic models developed in Phase I. Investigate the scalability of design and identify commonality efforts. Refine calculation and estimates provided in Phase I. This first-article prototype unit must also meet Navy unique requirements, such as shock and vibration in accordance with -S-901 - Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for [Ref 4] and MIL-STD-167-1 - Mechanical Vibrations of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited) [Ref 5], as well as Electromagnetic Interference in accordance with MIL-STD-461 - Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility Requirements for Characteristics of Subsystems and Equipment [Ref 6]. The final product will be a modernized first-article Size 25 Fan-Coil Assembly (FCA) which meets the test requirements established in the test plans developed during Phase I.

PHASE III DUAL USE APPLICATIONS: Following the successful design of the modernized FCA 25 and the satisfactory results of Phase II, the remainder of the series will be designed based on the qualified design and the company will assist the Navy in transitioning the technology for Navy use. Scale the results to design and develop the new series of modernized FCAs. To qualify the designs and collect data for future-program use, each size of the new FCA series will be installed on an operating Navy vessel, or

## VERSION 8

tested in such a way to qualify the unit(s) design. Comparisons of existing systems will be made so the energy usage of the modernized FCAs can be directly compared with similar legacy unit(s) that will operate under the similar shipboard parameters. Each unit's energy usage, system reliability, and maintenance will be assessed to inform the comparison. Demonstrate successful performance of the new series units to meet and/or exceed all specified modernized FCA requirements. It is envisioned that this development work for the remainder of the series will be covered by the program office(s) electing to integrate the modernized FCA line into their ship program.

Demonstrate large-sale manufacturability of the full series of FCAs, as well as provide maintainability support through operational and maintenance documentation. Develop the manufacturing plan, based on Navy-driven need for the units, and provide assistance with system integration as needed during Navy design efforts.

The development of the modernized FCA is envisioned to primarily benefit the Large Surface Combatant (DDG(X)) program, as well as future Navy ship programs. However, with much of the development carried out during the preceding Phases, the technology innovations developed through this project could be leveraged for potential back-fit modernization applications across the Surface Fleet. Current in-service ships in the Surface Fleet carry a total of between 30 and 50 total legacy FCAs, distributed among the different sizes in the family. This represents an opportunity to encourage commonality and form-fit-function design intent for the modernized version to help make back-fit more feasible.

Additionally, the innovation addressed in the project could potentially allow the company to expand its advantage in the industrial HVAC market. By designing the modernized FCAs with aerodynamically optimized air flow and airborne noise requirements, those innovations could inform the awardee's commercial product line to enhance air-side efficiency and reduce airborne noise, while meeting the unique cooling requirements for an industrial or residential setting.

### REFERENCES:

1. "MIL-PRF-23798D, PERFORMANCE SPECIFICATION: AIR CONDITIONER, FAN-COIL ASSEMBLY (13-DEC-2004)." [http://everyspec.com/MIL-PRF/MIL-PRF-010000-29999/MIL-PRF-23798D\\_15963/](http://everyspec.com/MIL-PRF/MIL-PRF-010000-29999/MIL-PRF-23798D_15963/).
2. "MIL-STD-1474D, Change Notice 1 - Change Notice 1, Noise Limits." [http://everyspec.com/MIL-STD/MIL-STD-1400-1499/MIL-STD-1474D\\_25106/](http://everyspec.com/MIL-STD/MIL-STD-1400-1499/MIL-STD-1474D_25106/).
3. "MIL-PRF-32168, PERFORMANCE SPECIFICATION: VARIABLE SPEED DRIVE SYSTEM FOR INDUCTION AND SYNCHRONOUS MACHINES (27 JUL 2004)." [http://everyspec.com/MIL-PRF/MIL-PRF-030000-79999/MIL-PRF-32168\\_19154/](http://everyspec.com/MIL-PRF/MIL-PRF-030000-79999/MIL-PRF-32168_19154/).
4. "MIL-DTL-901E, Detail Specification: Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for (20-JUN-2017) [SUPERSEDING MIL-S-901D]." [http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-901E\\_55988/](http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-901E_55988/).
5. "MIL-STD-167-1 - Mechanical Vibrations of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited)." [http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-167-1\\_22419/](http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-167-1_22419/).
6. "MIL-STD-461 - Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility Requirements for Characteristics of Subsystems and Equipment." [http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-461\\_8678/](http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-461_8678/).
7. "NAVSEA Releases Naval Power and Energy Systems Technology Development Roadmap." Team Ships Public Affairs, Naval Sea Systems Command, June 2019. <https://www.navsea.navy.mil/Media/News/Article/1888251/navsea-releases-naval-power-and-energy-systems-technology-development-roadmap/>. Roadmap document PDF: <https://www.navsea.navy.mil/Resources/NPES-Tech-Development-Roadmap/>.



## **VERSION 8**

8. Frank, Matthew V.; Helmick, Dick. 21st Century HVAC System for Future Naval Surface Combatants - Concept Development Report. NSWCCD-98-TR-2007. Naval Surface Warfare Center Carderock Division. September 2007. <https://apps.dtic.mil/sti/pdfs/ADA473662.pdf>.

KEYWORDS: V-belt fan driven; Navy Ventilation and Air Conditioning; Heating, Ventilation, and Cooling; HVAC; cooling coils; Variable speed; Fan Coil Assembly; Thermal Management

## VERSION 8

N221-055 TITLE: Improved Towed Array Acoustic Hose

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 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 towed array acoustic hose that prevents permanent hose deformation (creep), reduces water permeability, increases resilience against physical damage, and increases useful life.

**DESCRIPTION:** An improved hose for the acoustic modules of towed arrays for Navy submarines and surface combatants is desired. Current commercial state of the art for hosing on these acoustic modules leads to hoses that are often damaged by 1) marine life (e.g., shark bites), 2) fishing gear such as hooks and nets, and 3) typical wear and tear from vibration and torsion during normal operations. Further, there is reason to expect that it could be possible to improve the acoustic performance of the hose over the existing state of the art, which would enhance the ability of the towed array system to detect acoustic signals.

Towed arrays are streamed in the ocean by Navy combatants to detect underwater acoustic signals. Current towed array acoustic hoses are fluid-filled thermoplastic polyurethane (TPU) extrusions that contain towed array sensors and electronics. These hoses perform various functions to optimize towed array functionality and performance. The hose material provides some isolation from noise through a variety of factors (such as modulus, loss-tangent, material selection, and reinforcement design), protects the array from the surrounding environment, relieves some mechanical load on the array internal components during handling, storage, and shipping, and generally functions as the primary physical interface between the towed array and the environment. The hose typically experiences significant mechanical, environmental, and chemical stresses like high pressures, a wide range of temperatures, tension, torsion, vibration, exposure to seawater, isoparaffinic solvents, and so on. In addition to these harsh conditions, the hose is also often exposed to free floating fishing gear (known as “ghost fishing”), marine animal attack, abrasive surfaces, and other mechanically harsh situations.

The solution sought is expected to endure the aforementioned conditions for a period of at least 5 years before requiring replacement for any reason presuming a maximum of 25% array deployment at a maximum average of 15 knots across the 5 year period. The hose should resist physical damage due to sharp objects or abrasion (be at least 50% more cut-resistance than current hoses). The hose should reduce the ability of water to permeate the hose by at least 3 orders of magnitude over a 1-year period of immersion in sea-water. The hose should reduce mechanical creep by 2 orders of magnitude compared to legacy towed array hoses when exposed to axial loading for a period of up to 3 consecutive months.

In addition to achieving these requirements, the towed array hose must achieve the basic functions of legacy towed array hoses (listed below) and must not negatively impact towed array acoustic performance.

## VERSION 8

### Baseline Requirements:

- Temperature: -28°C to 60°C
- Pressure: -5 to 1200 psi
- Vibration: MIL-STD-167A
- Chemical:
  - o 5-year exposure to seawater
  - o 5-year exposure to ISOPAR L and/or ISOPAR M
- Suitable for reinforcement with various cords or yarns, such as Polyester, Kevlar, and Vectran
- Suitable for outside diameters of 1.1” to 3.5”
- Suitable for lengths up to 200’
- Suitable for hose wall thicknesses of 0.11” to 0.375” with a 125 micro-inches RMS surface finish
- Suitable for wrapping on drums with a d/D ratio of 1:24
- Suitable for achieving a leak-proof swaged or crimped termination
- Suitable for filling to a “firm and round” condition using internal pressure and maintaining that condition for 90 days
- Must not negatively impact towed array acoustic performance

The government will provide support for testing prototype assemblies in unique environmental testing facilities as required (such as towed array handling systems, long tension beds, large environmental chambers, etc.).

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

**PHASE I:** Develop a concept for an Improved Towed Array Acoustic hose that meets the requirements in the Description. Demonstrate the feasibility of the approach based on analysis, modeling, simulation, and evaluation. Demonstration must show an understanding and estimation of the critical performance factors as set for in the Description and explains that the approach is feasible. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build full scale prototype solutions in Phase II.

**PHASE II:** Develop and deliver a prototype Improved Towed Array Acoustic hose based on the results of Phase I and the parameters in the Description. A number of prototype hose samples may be required for testing and evaluation to be conducted. The system will be evaluated, tested, and certified by the government.

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

**PHASE III DUAL USE APPLICATIONS:** Assist the Government in transitioning the technology to Navy use. This will include experimentation and refinement of the prototype to qualify the technology for use on towed arrays. The government will provide the performer access to a Navy ship or research vessel where the final system validation and performance verification will be conducted. Support installation and

## VERSION 8

removal from a test platform and assist in data analysis and interpretation. Existing data will be used to verify the measurements and accuracy of the system.

This system would prove useful for oceanographic research, oil and gas exploration, and potentially any industry where rugged, flexible, chemically resistant hoses are used, such as transportation, industrial plants, and automotive.

### REFERENCES:

1. Lemon, S. G. "Towed-Array History, 1917-2003", IEEE Journal of Oceanic Engineering, Vol. 29, No. 2, April 2004, pages 365 – 373, <http://ieeexplore.ieee.org/abstract/document/1315726/>. Locate libraries that hold this title at [https://www.worldcat.org/title/towed-array-history-1917-2003/oclc/198436243&referer=brief\\_results](https://www.worldcat.org/title/towed-array-history-1917-2003/oclc/198436243&referer=brief_results).
2. Burdic, William S. "Underwater Acoustic System Analysis", New Jersey: Prentice-Hall, Inc., 1991. Locate libraries that hold this title at [https://www.worldcat.org/title/underwater-acoustic-system-analysis/oclc/70580566&referer=brief\\_results](https://www.worldcat.org/title/underwater-acoustic-system-analysis/oclc/70580566&referer=brief_results).
3. "AN/SQQ-89(V) Undersea Warfare / Anti-Submarine Warfare Combat System," Navy Fact File. <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166784/ansqq-89v-undersea-warfare-anti-submarine-warfare-combat-system/>.

KEYWORDS: Towed Array; Hose Deformation; Towed Array Sensor; Cut-Resistance; Water Permeability; Mechanical Creep

## VERSION 8

N221-056 TITLE: Unmanned, Autonomous Avoidance of Active Acoustics Harassment of Marine Mammals

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 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:** Investigate and develop a conceptual design for a model prototype with a low-power, autonomous marine mammal harassment mitigation or avoidance capability for use during active sonar operations of unmanned, autonomous Deployable Surveillance Systems (DSS), whose feasibility is demonstrated using modeling and simulation (M&S).

**DESCRIPTION:** The U.S. Navy has been and continues to be a leader in environmental stewardship for maintaining a healthy marine ecology of the world's oceans through its heavily funded research and environmental protection practices. Moreover, federal regulations have invoked certain policies for Navy to use mitigation practices in order to avoid harassment or injury to marine mammals when operating active sonar during training and testing operations. At the same time, federal law requires the Navy, under Title 10 of the U.S. code, to uphold its military obligation to defend the security interests of the nation that include use of its active sonar during training and testing operations during peacetime in order to maintain wartime readiness. The Navy continually sustains the required balance to keep in compliance with both federal laws. The scope of this SBIR topic concerns continuing to maintain this balance for DSS. Current mitigation practices enforced by the Navy require a human in-the-loop for visual sightings of nearby surfaced marine mammals during daytime operations of active sonar and/or passive acoustics to detect nearby vocalizing marine mammals during training and testing exercises. A technical problem/challenge for the proposer is to provide an innovative solution for conducting autonomous active sonar DSS operations by developing an unmanned, autonomous mitigation prototype without the requirement of human intervention for performing mitigation or avoidance procedures. DSS are a family of unmanned, autonomous systems which provide acoustic surveillance mission capabilities for maritime theater undersea warfare. Transition of DSS capability is accomplished through systems increments and spiral developments.

DSS is a middle-tier acquisition program with rapid-prototyping and rapid-fielding demands which necessitate modularity and shorter timeframes to transition DSS increments and spiral capabilities while still considering total ownership costs over the life of the capability (e.g., development, test/evaluation, sustainment, manufacturing, modernization, obsolescence, sunset) to transition the capability.

The purpose of an autonomous prototype is to: (a) detect vocalizing marine mammals with passive acoustic sensor(s) in the harassment range of active sonar operations; (b) replace the human lookout/on watch to look for non-vocalizing marine mammals; (c) make autonomous decisions to ascertain the presence of animal(s) in vicinity of operations in which case the sonar cannot go active; and (d) reduce active power emissions or turn off active sonar, as appropriate, if marine mammals are detected within a prescribed harassment area. The desired built-in prototype capability shall have low-power and shall be

## VERSION 8

integrated into the autonomous prototype as a 'go/no go' decision for using active acoustics (vice as a modeling tool for understanding acoustic impact to marine mammals).

DSS systems, which may use active acoustics during operations, will need to avoid harassment of marine mammals, which could result in behavior modification or harm to marine mammals. Current military active acoustic harassment mitigations all include manned (human in-the-loop) operations.

The Navy needs an innovative solution that provides the ability to sense/detect, without any human involvement, marine mammals (whether vocalizing or not) that are within range of active acoustics harassment and prevent such harassment from occurring. If a potential harassment situation occurs, the goal is to provide and integrate decision-making algorithms to the DSS system to prevent, without any human involvement, such harassment with least impact to the DSS maritime surveillance mission that requires employment of its active sonar.

The solution must provide an energy-efficient capability that does not negatively impact power and energy needs in other areas of DSS system operations. Energy consumption is just one of many other examples. In a second example, when no marine mammals are present in the operating area and mitigation steps are not being required to reduce DSS operational source level, the automated marine mammal harassment mitigation prototype should not cause any interference or degradations to DSS normal mission/sonar operational performance capability. In a third example, the DSS prototype may be provided with a communications link to command authority with a mitigation disabling option for wartime combat missions. These are just a few trade-space examples. Offerors are asked to research, develop, and demonstrate new solutions to the stated problem.

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

PHASE I: Develop a conceptual design for an energy-efficient low-power, autonomous marine mammal harassment mitigation or avoidance capability, an innovative technology solution that will fill the current technology gap.

Base the solution on a model design identifying key elements that are used to determine the technical feasibility of the approach through computer modeling and simulation, and best available science. (Note: Examples of the available science on marine mammals and sonar technologies are provided as illustration in references 1 through 3.)

Identify anticipated performance milestones.

Demonstrate, via computer modeling and analysis, the operational feasibility for fielding the modeled design for a Phase II prototype build, test, and at-sea demonstration.

Provide: (a) a detailed description of the concept design (hardware and software) architecture; (b) description of the analytical approach, the methods and results of computer modeling and simulation

## VERSION 8

(M&S) performed as a basis for justifying the proposed architecture; and (c) the plan for incorporating the proposed architecture into a prototype build in Phase II (Phase I Option).

The Phase I Option, if exercised, will include notional design specifications and a capabilities description to build a prototype in Phase II. Include how total operating costs of the solution can be addressed while maintaining state-of-the-art advances as future DSS increments and spirals are transitioned, for example, additive manufacturing, advanced materials, modularity of subcomponents.

PHASE II: Implement the proposed architecture developed in Phase I and deliver and test at-sea a prototype to implement an unmanned, autonomous solution for avoidance of active acoustics harassment of marine mammals for effective use of DSS systems using active acoustics. The feasibility of the proposed solution will be demonstrated in a variety of potential ocean environments, system integration architectures, and for mission concepts of operation using modeling tools. Build and demonstrate components or sub-components of the system to validate the accuracy of the model.

Validate that the prototype operates in accordance with the model in a laboratory or at-sea environment. Incorporate lessons learned from simulated computer simulation and modeling, actual at-sea acoustic measurement trials, and analysis of the collected test data into a full system design. A final prototype will be delivered at the end of Phase II.

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

PHASE III DUAL USE APPLICATIONS: Provide total operating costs of a transitioned capability (including but not limited to manufacturing, integration, deployment, sustainment, and modernization).

Support the Navy in transitioning the technology to Navy and commercial use. Further refine, fabricate, and implement the developed hardware and/or software to suit the operation of a capability for DSS systems to avoid active acoustics of marine mammals and support testing in laboratory and ocean environments to meet requirements for functionality, environmental extremes, reliability, safety, and other requirements to certify the system for Navy use. (Note: The Navy will support operational testing.) Deliver hardware/software, related documentation, support installation on existing systems, and retrofit technology for use in operational testing.

Provide an execution plan for commercial dual-use application of the advanced technology. One example of a technology application of an autonomous mitigation prototype device for dual-use in the commercial sector is in the commercial fishing and shipping industries for possible mitigation of net entanglements, bi-catch, and ship strikes.

### REFERENCES:

1. Finneran, J., Henderson, E., Houser, D., Jenkins, K., Kotecki, S., Mulsow, J., "Criteria and Thresholds for U.S. Navy Acoustic and explosive Effects Analysis (Phase III)," Space and Naval Warfare Systems Center Pacific (SSC Pacific) Technical Report June 2017.
2. Hawaii-Southern California Training and Testing Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS); <https://www.hstteis.com>.
3. Erbe, C., Reichmuth, K., Cunningham, K., Lucke, K., Dooling, R., "Communication masking in marine mammals: A review and research strategy," 15-38, Elsevier Publ. Marine Pollution Bulletin (2015), <http://dx.doi.org/10.1016/j.marpolbul.2015.12.007>.
4. NOAA National Marine Fisheries Service: Marine Mammal Acoustic Technical Guidance, 2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing.

## VERSION 8

5. National Oceanographic and Atmospheric Administration (NOAA), U.S. Department of Commerce; <https://www.noaa.gov/fisheries-regulations-permits-data-reporting-restoration-projects>.

KEYWORDS: Marine Mammal Harassment; Active Acoustics; Maritime Surveillance; Theater Undersea Warfare; behavioral response; auditory sensitivity



## VERSION 8

N221-057 TITLE: Alternative Power for Anti-Submarine Warfare Targets

OUSD (R&E) MODERNIZATION PRIORITY: 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 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 alternate power source greater than 3.6 KWhrs in a 6.75 inch diameter by 30 inch length extended endurance section for the MK39 Expendable Mobile Anti-Submarine-warfare Training Target (EMATT).

DESCRIPTION: Anti-Submarine Warfare (ASW) training is conducted most effectively when air, surface, and subsurface platforms train in the operational environment. Training against live submarines is costly and often not available; therefore, mobile ASW training targets fill this critical training need. The addition of a larger and higher density power source to the MK39 EMATT would give its users more options to improve its emulation of a submarine for ASW proficiency training. The baseline MK39 EMATT is powered by a Li SO<sub>2</sub> battery capable of doing 3 to 8 knots, is very high in energy density, is low cost, has a long active life, contains lithium metal, and is pressurized. The existing battery uses L026SXC cells manufactured by SAFT, Inc. The battery pack consists of two (2) parallel strings of fifteen (15) D-size L026SXC cells connected in series (15S2P). This provides a 45 Volt (V) power source with a capacity rating of 16 Ampere-hours (Ah). Each string is protected by redundant diodes and the pack is fused with an 8 amp slow blow fuse. The existing form factor is much smaller than the 6.75 inch diameter by 30 inch length extended endurance section to be investigated under this SBIR effort.

The objective is to develop an alternative power source that accomplishes the requirements and meets the goals set by the MK39 EMATT program and ASW targets.

The Navy is in need of an innovative way of powering the MK39 EMATT and ASW targets. The SBIR topic seeks development of a power source that is expended after one use that is not required to be recharged. This SBIR effort would evaluate concepts based on specific needs such as endurance and sprint speed. Currently there are emerging methods such as fuel cell, battery paper, carbon zinc, etc. both commercially and in Government. Increasing the power capabilities of an ASW training target will make it more realistic to real world threats. Also, with increased power ASW targets will have a wider range of capabilities. This includes increased speed, additional sensors, and increased endurance. With the addition of an extended endurance section to the EMATT that is 6.75 inch diameter by 30 inch length, the cg (Center Of Gravity) becomes an issue to investigate as the EMATT is negatively buoyant. The goal is to have a cg of -1.5 inches or less below the center of buoyance. The goal for buoyancy of the section to be approximately neutrally buoyant.

An innovative way of powering the MK39 EMATT and ASW targets should enable a longer run time per vehicle, looking at approximately an objective time of 24 hours. Desired voltage is to maintain the baseline 45Volts. Estimated amperage required for the speed range of the larger vehicle is approximately

## VERSION 8

10-15 amps. Driving down the cost per hour below \$100 per hour is also desired. The Navy would like to develop and build thirty to forty prototype power sources for testing and evaluation.

System performance will be demonstrated through bench and safety testing. The awardee will perform bench testing, at the awardee's facility, to determine if the prototype meets size, weight, and power. Bench testing is expected to be conducted halfway through the Phase II effort. Evaluation results will be used to refine the prototype into an initial design that will meet Navy requirements. Conduct safety testing in accordance with Navy lithium safety program responsibilities and procedures of S9310-AQ-SAF-010 [Ref 1] as applicable with Naval Surface Warfare Center Carderock. Conduct safety testing in accordance with High-Energy Storage System Safety Manual, SG270-BV-SAF-010 [Ref 2] with Naval Surface Warfare Center Carderock. Safety testing will be conducted at the end of the Phase II effort. The prototype shall meet operational temperature requirements of -5°F to 135°F. The prototype shall meet operational vibration requirements of exposure to a random vibration of 20 Hz to 1126 Hz for duration of 3 hours. The prototype is not required to meet any operational shock requirements, however the prototype design shall be evaluated to determine shock survivability.

**PHASE I:** Develop an initial concept design and feasibility of an extended endurance power source. Consider how the candidate alternate power supply can be integrated into the ASW mobile training target. Provide design data and analysis to substantiate the findings. Demonstrate the feasibility of the concept to meet the parameters listed in the Description through modeling, simulation, and analysis. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Based on the results of Phase I and the Phase II Statement of Work (SOW), the small business will develop and deliver a prototype for evaluation as appropriate. Approximately Thirty power sources shall be built for testing and evaluation. The prototype will be evaluated to determine its capability in meeting the performance goals defined in the Phase II SOW. System performance will be demonstrated through prototype evaluation as described in the Description. Evaluation results will be used to refine the prototype into an initial design that will meet Navy requirements. Conduct safety testing in accordance with Navy lithium safety program responsibilities and procedures of S9310-AQ-SAF-010 as applicable. Conduct safety testing in accordance with High-Energy Storage System Safety Manual, SG270-BV-SAF-010. Conduct environmental testing.

**PHASE III DUAL USE APPLICATIONS:** Support the Navy in transitioning the technology to its intended platform for Navy use. Develop the extended 6.75 inch diameter by 30 inch length extended power source for evaluation to determine its effectiveness in an operationally relevant environment. Support the Navy for test and validation to certify and quantify the system for Navy use. The developed power source will be transitioned for use in the MK39 EMATT and other ASW targets.

Compact High-Energy Storage Systems are in demand for a variety of commercial applications including automobiles, unmanned undersea vehicles, emergency and portable power systems, and residential storage.

### REFERENCES:

1. "S9310-AQ-SAF-010: NAVY LITHIUM BATTERY SAFETY PROGRAM RESPONSIBILITIES AND PROCEDURES." NAVSEA Technical Report, 03 November 2020. [https://navysbir.com/n21\\_1/Topic-N211-033-Reference\\_Document\\_S9310-AQ-SAF-010-Rev3.pdf](https://navysbir.com/n21_1/Topic-N211-033-Reference_Document_S9310-AQ-SAF-010-Rev3.pdf).
2. "SG270-BV-SAF-010 High-Energy Storage System Safety Manual (27-April-2011)." [http://everyspec.com/USN/NAVSEA/SG270-BV-SAF-010\\_27APR2011\\_50446/](http://everyspec.com/USN/NAVSEA/SG270-BV-SAF-010_27APR2011_50446/).

## VERSION 8

3. Staffell, Iain, Scamman Daniel, Balcombe Paul. "The role of hydrogen and fuel cells in the global energy system" Energy & Environmental Science, 10, December 2018.
4. Technical Manual: Expendable Mobile ASW Training Target (EMATT), Mark 39 MOD 3, Description, Operation, Launch, and Handling.
5. "High Rate DD Cell Lithium Sulfuryl Chloride." Electrochem An Integer Company : 8 December 2020. <https://s24.q4cdn.com/142631039/files/pdf/3B0036-datasheet.pdf>.

KEYWORDS: energy source; energy density; endurance; Anti-Submarine Warfare; ASW targets; Expendable Mobile Anti-Submarine Warfare Training Target; MK39 EMATT; advanced power source

## VERSION 8

N221-058 TITLE: Electronic Warfare Human Machine Interface Training

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 game-based, dynamic Electronic Support Measures (ESM) training prototype utilizing TI-20 AN/BLQ-10 automation, displays and capabilities to include realistic scenarios and environmental factors enabling stress-habituation.

**DESCRIPTION:** The operation of modern submarines is complex and requires continuous training to learn how to effectively operate the warfighting systems. The current trend is to extend classroom training with advanced training techniques through the Navy's "Sailor 2025" program. This program describes the urgent need for Ready, Relevant Learning (RRL) to ensure that sailors have the warfighting skills they need. RRL requires a reconstruction of training techniques, adaptability of training location (i.e., standalone systems, classroom-based workstations, or cloud-based programs), a learning continuum (to ensure skill acquisition, mastery and maintenance), and requires that training products take advantage of the latest in learning technology (i.e., serious games and YouTube-like videos). The focus of this SBIR topic is discovering the best combination of cognitive experiences and computer-guided gamification learning techniques. Coupled with existing combat system simulation systems, the trainer will use cognitive training techniques to teach sailors how to effectively learn and operate advanced Electronic Support Measures (ESM) systems quickly and accurately. This SBIR effort is about connecting with each individual and coaching them to reach their highest potential using advanced training capabilities.

PMS-435 seeks to develop an engaging, multi-modal, performance-based ESM trainer that addresses the Navy's vital need for RRL by amending the deficiencies of the current AN/BLQ-10 Computer-Based Training (CBT) as well as the lack of commercially available software to adapt to such a need by utilizing the automation and advanced displays associated with the TI-20 upgrade to the AN/BLQ-10 system. This SBIR topic seeks development of innovative training techniques and their integration with a performance-based navigation engine. The state-of-the-art trainer shall utilize an innovative training engine that calculates in-situ proficiency measurements, which provide unique learning paths through the material. The training engine will be implemented with three additional innovation areas to develop a unique trainer that accelerates learning and improves performance. The following areas of innovation are to be addressed by this trainer:

1. **Dynamic Training Scenarios:** The current AN/BLQ-10 CBT uses a pre-defined calibrated set of scenarios to measure performance and drive navigation. Continued use of CBT indicates that sailors become accustomed to the existing scenarios, therefore diminishing its effectiveness. The solution involves the development of a dynamic scenario generator that enables endless variances of scenarios and ensures a unique training experience each time the CBT is used. This innovative generator will incorporate traditional navigation methods with innovative techniques that allow scenarios to fit into the robust algorithms as they are made.

## VERSION 8

2. **Gamification:** Develop software that leverages game-based learning for its innovative training solution. Game-based learning, or gamification, is a novel teaching approach that utilizes certain gaming principles (i.e., badges, points, and leaderboards) and applies them to training practices. Studies show that gamification increases user engagement and keeps trainees in the zone of engaged development – improving skill acquisition and retention, while maintaining an exciting and entertaining game. This shall be accomplished by implementing an engaging, game-like environment with multi-modal, robust training methodology. The gamification approach shall follow extensive research on this topic in commercial gaming.
3. **Stress-habituation:** Sailor stress elicits physiological and emotional responses that diminish warfighting decision-making performance. Presently, the sailor is trained to read and analyze various electromagnetic warfare (EW) phenomena to make tactical decisions but does not learn how to operate under severe stress. The proposed trainer shall institute modalities that habituate sailor stress during the training cycle to utilize the brain's experience-dependent neuroplasticity. This refers to the brain's capacity to change in response to experience, repeated stimuli, environmental cues, and learning. The training solution will expose the sailor to stressful stimuli such that the brain adapts and becomes more tolerant of and less reactive toward stress, consequently preparing them for warfighting experiences.

The core of this SBIR research effort is to determine how to accelerate learning and improve stress-related responses using psychological methodologies to fulfill the Navy's need for RRL. The results will provide metrics for determining the level of each trainee's improvement during a training session, and these metrics will be logged over time. The pursued innovation will provide each trainee the ability to improve his/her training efficiency and learning retention as well as enhance their actual performance. By addressing the foundational skills at a deep level in which the sailor can act nearly instinctively in their role, the Navy will have expanded capabilities and create an advantage that empowers the fighting force with expertise in their actions and supports fielding a precision team. This is to be accomplished by developing a training solution based on the following parameters:

1. Define and develop a hardware and software architecture trainer concept that would connect to the submarine TI-20 AN/BLQ-10 system,
2. Define metrics for measuring stress and determine how to implement stress factors into the trainer,
3. Develop methods to implement and utilize dynamic scenarios, and
4. Produce a conceptual design of a game-based, dynamic, performance-based trainer and model key components such as TI-20 AN/BLQ-10 interface display, operator performance, stress metrics, and course content.

The innovative training solution shall maximize learning and gaining proficiency through easily accessible learning and training platforms. This trainer would ideally be viewed through various learning platforms, such as the Moodle Learning Management System, the Multifunctional Instructional Trainer (MIT) and/or the Submarine On Board Training (SOBT). Integration onto these platforms will enable the use of multiple, concurrent training sessions and ensure the widespread use of the trainer.

Initial testing of this trainer can be accomplished at the company site, where TI-20 automation and advanced display capabilities shall be applied in a performance-based training environment. This testing will be conducted by the developer with Government representatives. Final testing and certification will occur at the prime system integrator site and will be conducted by Government representatives in collaboration with Naval submarine force active-duty operators.

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

## VERSION 8

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

PHASE I: Develop a concept for an improved ESM trainer that incorporates dynamic scenarios, gamification, and stress habituation for inclusion as part of the TI-20 AN/BLQ-10 system per the requirements in the Description. Demonstrate the feasibility of the concept to meet the described parameters listed in the Description through modeling, simulation, and analysis. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Using results from Phase I, develop, validate, and deliver the prototype for an improved ESM trainer that establishes modalities to acclimatize sailor stress. The operator interface will emulate and directly interact with the TI-20 AN/BLQ-10 operator machine interface. System performance will be demonstrated through prototype evaluation and modeling or analytical methods over the required range of parameters. Develop and demonstrate a dynamic scenario environment via the generation of multiple scenario variances. Develop and demonstrate an engaging, game-based training environment that mirrors TI-20 AN/BLQ-10 displays. Develop and demonstrate environmental factors that take advantage of experience-dependent neuroplasticity and habituate stress. Implement and test the dynamic, game-based training prototype. The field test data collection should demonstrate that operators have an improved resilience and reaction to stress-inducing environments as well as demonstrate skill level improvements in comparison to operators that use traditional TI-20 AN/BLQ-10 training methods.

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

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use in which the final product delivered to the Navy will be an improved ESM trainer that incorporates dynamic scenarios, gamification, and stress habituation to increase operator skill and proficiency in employing the TI-20 AN/BLQ-10 system in a variety of operating environments. This trainer will be incorporated into the TI-20 update to the AN/BLQ-10 system on designated submarines. Work with the associated Integrated Product Team (IPT) and provide hardware and/or software to the system prime contractor for inclusion and integration. The improved ESM trainer performance will be evaluated as part of the overall TI-20 AN/BLQ-10 system testing and evaluation.

Dual use potential exists for any field where operator performance is or could be tracked and developed using CBT. Examples of potential applications include:

1. Operator response to system failures in power generation or manufacturing plants, ensuring systems are placed in a safe condition for subsequent troubleshooting and repair.
2. Operator response to vehicle and/or control system failures in transit systems, such as air traffic control, railway signaling, and subway signaling.
3. Operator response to system failures in commercial shipping vessels.

#### REFERENCES:

1. Wemm, Stephanie E., and Wulfert, Edelgard. "Effects of Acute Stress on Decision Making." *Applied Psychophysiology and Biofeedback*, vol. 42, no. 1, 2017, pp. 1–12., doi:10.1007/s10484-016-9347-8, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5346059/>.

## VERSION 8

2. Porcelli, Anthony J, and Delgado, Mauricio R. “Stress and Decision Making: Effects on Valuation, Learning, and Risk-Taking.” *Current Opinion in Behavioral Sciences*, vol. 14, 2017, pp. 33–39., doi:10.1016/j.cobeha.2016.11.015,
3. Dicheva, Darina. “Gamification in Education: A Systematic Mapping Study.” *Journal of Educational Technology & Society*, vol. 18, no. 3, 1 July 2015, pp. 75–88. JSTOR, [www.jstor.org/stable/10.2307/jeductechsoci.18.3.75?refreqid=search-gateway:99da2592a1aba73429161d0e017cb0e6](http://www.jstor.org/stable/10.2307/jeductechsoci.18.3.75?refreqid=search-gateway:99da2592a1aba73429161d0e017cb0e6).
4. Davidson, Richard J, and McEwen, Bruce S. “Social Influences on Neuroplasticity: Stress and Interventions to Promote Well-Being.” *Nature Neuroscience*, vol. 15, no. 5, 2012, pp. 689–695., doi:10.1038/nn.3093.

KEYWORDS: Electronic Support Measures; Game-Based Training; Gamification; Experience-Based Neuroplasticity; Electronic Warfare; Sailor 2025

# VERSION 8

N221-059 TITLE: Directional Acoustic Communications Transmitters

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy

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 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 directional acoustic transmitters that can be scaled for use on medium, large, and extra-large unmanned undersea vehicles (UUVs).

DESCRIPTION: The Navy seeks to develop directional acoustic transmitters for use on UUVs. The commercial market lacks directional transducers appropriate for UUV integration/usage due to lack of commercial demand/use cases for such a capability. The closest commercial equivalents would be spherical arrays targeted for vertical (in water column) applications, but such arrays are not suitable for the UUV applications targeted by the Navy. Directional acoustic transmitters will enable the Navy to more effectively conduct UUV swarming operations by reducing mutual interference, as well as more clandestine communications by directing the transmitted acoustic beam pattern main response axis (MRA) toward the intended receive array. Current commercial UUV transmit/receive transducers project omni-directional acoustic energy in all directions, whereas directional transmitters are generally limited to larger manned platforms such as submarines. Development of directional projectors compatible with size, weight, and power (SWaP) constraints of UUVs is challenging. The available SWaP within UUVs varies greatly by class and design, but rough order of magnitude (ROM) allowances are provided in the table below. It is noted that the values in this table are provided for guidance only – they are not to be considered formalized requirements against which the proposals will be adjudicated.

UUV Class	Medium	Large	Extra-Large
ROM Volume:	216 in <sup>3</sup> (6" cube)	1728 in <sup>3</sup> (12" cube)	5832 in <sup>3</sup> (18" cube)
ROM weight in air:	8 lbs	64 lbs	216 lbs
ROM Tx Power:	250W	350W	500W
ROM Standby Power:	5W	10W	20W

These SWaP challenges are exacerbated by the requirement to withstand large hydrostatic pressures experienced during UUV missions. Larger projectors are required to generate narrower/more focused beams, so a prime challenge is optimizing the transmitter to fit within the existing UUV platforms. Another challenge is the pointing of the transmit beam, i.e., its MRA as well as its width while



## VERSION 8

maintaining sidelobe rejection at other angles. For longer ranges (> 1km) acoustic transmission paths are more complex and require knowledge of the environment and a modeling capability. In addition to development of the directional transmitters, proposers should include the pointing method of the resultant beam, control of the beam's sidelobes and the main lobe width, minimizing size, weight, power, and cooling (SWaP-C) associated with the solution, and the novelty of the approach.

The technical merit of the proposed solutions will be evaluated on factors including:

1. Ratio of the energy to the targeted region vs. the energy transmitted over the entire (360°) geographic region
2. Required level of in-situ environmental knowledge in order for the transmitter to point itself and achieve the focused gain described in #1
3. Transmitter gain over a variety of environmental and bathymetric conditions
4. Maximum volume and maximum physical or synthetic transmit aperture dimension
5. Estimated weight of the system
6. Maximum power draw by the transmitter when in use and during standby
7. Suitability of chosen projector technology to operate/survive over the variety of operational depths over which PEO-USC UUVs operate

The company will test the prototype system, first in a controlled laboratory environment, then in an in-water (saltwater) environment, to determine its capability to meet all relevant performance metrics outlined in the Phase II SOW. Testing shall characterize the optimization of directional transducer control, coupled with the communication function, in the presence of interfering and mutual interference of external assets. The company shall demonstrate the prototype system performance in both environments (laboratory and in-water) to the Government and present the results in two separate test reports.

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

PHASE I: Develop a concept for a directional acoustic transmitter that meets the requirements in the Description. Establish feasibility by developing system diagrams as well as Computer-Aided Design (CAD) models that show the transmitter concept and provide estimated weight and dimensions of the concept. Feasibility will also be established by computer-based simulations that show the transmitter's pointing capabilities are suitable for the project needs. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Based on the results of Phase I and the Phase II Statement of Work (SOW), develop and deliver a prototype system for in-water testing and measurement/validation of the Phase I performance attributes. Test the prototype system, first in a controlled laboratory environment, then in an in-water (saltwater) environment, to determine its capability to meet all relevant performance metrics outlined in the Phase II SOW. Testing shall characterize the optimization of directional transducer control, coupled with the communication function, in the presence of interfering and mutual interference of external assets. Demonstrate the prototype system performance in both environments (laboratory and in-water) and

## VERSION 8

present the results in two separate test reports to the Government. Use the results to correct any performance deficiencies and refine the prototype into a pre-production design that will meet Navy requirements. P Prepare a Phase III SOW that will outline how the technology will be transitioned for Navy use.

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

**PHASE III DUAL USE APPLICATIONS:** If successful, in addition to UUV applications, these directional acoustic transmitters could be applied to other unmanned Navy assets including buoys and subsea nodes. These assets have communications requirements, some of which require clandestine communications, for which these directional acoustic transmitters could provide a solution. In addition to such DoD applications, these directional acoustic transmitters could be used in commercial oil, gas, and oceanographic sensing applications, where the prevention of mutual interference between submerged assets is required.

### REFERENCES:

1. Freeman, Simon. "A highly directional transducer for multipath mitigation in high-frequency underwater acoustic communications." *The Journal of the Acoustical Society of America* 138(2):151-154. August 2015. <https://doi.org/10.1121/1.4928278>.
2. Stojanovic, Milica. "Retrofocusing techniques for high rate acoustic communications." *The Journal of the Acoustical Society of America* Volume 117, 2005: 1173-1185. March 11, 2021 <https://doi.org/10.1121/1.1856411>.
3. N. Fruehauf and J. A. Rice, "System design aspects of a steerable directional acoustic communications transducer for autonomous undersea systems," OCEANS 2000 MTS/IEEE Conference and Exhibition. Conference Proceedings (Cat. No.00CH37158), Providence, RI, USA, 2000, pp. 565-573 vol.1, doi: 10.1109/OCEANS.2000.881315.

**KEYWORDS:** Transducers; acoustic communications; clandestine communications; swarming UUVs; mutual interference; beam pointing; in-situ environmental collection.

## VERSION 8

N221-060 TITLE: Chip Scale Oceanographic Sensor

OUSD (R&E) MODERNIZATION PRIORITY: Microelectronics

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Create a chip scale oceanographic sensor that can be integrated onto a ship or unmanned underwater vehicle (UUV) hull to accurately measure ocean water chemistry in real-time.

DESCRIPTION: A new generation of measurement technology is developing new, ultra-compact, ultra-reliable, low-power sensors with accuracy linked by a known degree of error to U.S. standard measurements. Partnerships with industry are developing fabrication processes similar to existing microelectromechanical systems (MEMS) that will manufacture these sensors as a rugged and inexpensive device. These new developments offer a new opportunity for the submarine community to access and utilize environmental data on the outer hull of a submarine. At present, these sensors have not been ruggedized to reliably function in the harsh environments the external hull of a U.S. Navy submarine endures during its service life. This SBIR topic seeks a hull-mounted (i.e., external) chip scale sensor for in-situ monitoring of oceanographic chemical parameters.

To protect against corrosion, a ship's Impressed Current Cathodic Protection (ICCP) distributes electrical energy between sections of the hull. The ICCP control system measures voltages using seawater silver/silver-chloride reference electrodes and adjusts the electrical potentials appropriately. Changes in seawater chemistry near the hull will change the electrical potentials, creating the need for a real-time oceanographic measurement input to the ICCP feedback control. The objective of creating a chip scale sensor should integrate the following threshold oceanographic chemical parameter measurements into a single device without causing interference on the reference electrodes:

- Temperature:  $0-50 \pm 0.1$  °C
- pH:  $7-11 \pm 0.1$
- Conductivity:  $1-6 \pm 0.001$  S/m
- Dissolved oxygen:  $1-14.6 \pm 0.1$  ppm [2]
- Sampling rate of at least one per minute (required)
- Additional chemical parameters of interest include: chloride ( $\pm 0.1$  mg/L), bromide ( $\pm 0.1$  mg/L), sodium ( $\pm 0.1$  mg/L), calcium ( $\pm 0.1$  mg/L), sulfate ( $\pm 0.1$  mg/L), and sulfide ( $\pm 0.1$  mg/L)

These sensors will modernize the ICCP system to provide real-time ambient oceanography measurements that correlate with noise on cathodic protection reference cells. This will enable minimum impressed current emissions while still maintaining cathodic protection of the hull. The Naval Research Lab (NRL) has started modifying the ICCP controller to accept these oceanographic inputs, and has historic studies documenting the correlations between the oceanographic chemical parameters and corrosion polarization curves.

It is essential that the sensors maintain these accuracies under environmental stresses experienced by underwater hulls. These conditions include: temperature  $0-50$  °C, hydrostatic pressure cycling from  $0-10,000$  kPa, grade B shock requirements from MIL-DTL-901E [Ref 1] without leakage when subjected to hydrostatic pressure, total suspended solids of  $0-120$  mg/L, fouling and biofouling over extended deployment periods. Chip scale sensors have been demonstrated for the identified parameters and proposals should identify the sensors that are envisioned for integration. The integrated sensor should fit in a space less than  $10.0$  cm x  $7.5$  cm x  $5.0$  cm, use less than  $10$  watts of power, meet the Navy's goal of a  $20$ -year lifetime, and utilize low-cost MEMS manufacturing methods. Smaller sensors that meet these requirements will leave space for additional future sensors.

## VERSION 8

PHASE I: Develop a concept for an integrated sensor that achieves the needed measurement accuracy under temperature and pressure cycling presented in the Description. Determine the feasibility of the concept to meet the described parameters listed in the Description through modeling, simulation, and analysis. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver two prototypes of a chip scale sensors. Modify the sensors as needed and integrate the sensor package into a shipboard ICCP reference electrode holder. Demonstrate the prototype's performance under the necessary environmental stresses: one month in a natural seawater environment where biofouling colonization is prevalent, such as Port Canaveral, FL. Certification of the natural seawater test environment will be conducted by the Naval Research Laboratory and Naval Surface Warfare Center, but the testing and evaluation will be conducted by the performer. Required hydrostatic pressure cycle evaluation will be conducted under laboratory conditions at the Naval Research Laboratory using a seawater pressure chamber. Documentation of all Phase II testing results should include independent parameter measurements documenting required accuracy. Identify the largest costs in manufacturing the sensor and assess cost reduction measures.

Deliver, for the environmental exposure demonstration, two packaged sensors for Navy evaluation.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through system integration and qualification testing. Integrate the sensor package into the shipboard ICCP architecture and data acquisition system as part of a Temporary Alteration (TEMPALT). Demonstrate environmental exposure operation of the sensor package for a minimum of two years. Implement cost reduction measures and install sensors aboard a ship at multiple reference electrode locations. Mortality analysis and documentation of any failed elements will be required. This sensor can provide a low Size, Weight, Power and Cost (SWAP-C) replacement for existing oceanographic sensors, which are routinely used for oceanographic surveys or environmental ocean monitoring. Reassess and document the largest costs in manufacturing the sensor as well as cost reduction mitigations.

### REFERENCES:

1. "MIL-DTL-901E, DETAIL SPECIFICATION: SHOCK TESTS, H.I. (HIGH-IMPACT) SHIPBOARD MACHINERY, EQUIPMENT, AND SYSTEMS, REQUIREMENTS FOR (20-JUN-2017) [SUPERSEDING MIL-S-901D]." [http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-901E\\_55988/](http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-901E_55988/).
2. NIST on a Chip, <https://www.nist.gov/noac/introduction>.
3. Wei, Yaoguang et al. "Review of Dissolved Oxygen Detection Technology: from Laboratory Analysis to Online Intelligent Detection." *Sensors (Basel)*, Sep 2019. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6767127/>.
4. National Oceanography Centre, Southampton, UK, <https://www.noc.ac.uk/technology/technology-development/instruments-sensors>.

KEYWORDS: Oceanographic chemical analysis; Microelectromechanical Systems; MEMS; Impressed Current Cathodic Protection; Corrosion Protection; Measurement-science sensor; Underwater Electromagnetic Signatures

## VERSION 8

N221-061 TITLE: Kill Assessment and Closely Spaced Object Resolution with Elevated Electro-Optic/Infrared (EO/IR)

OUSD (R&E) MODERNIZATION PRIORITY: Directed Energy (DE)

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 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 Electro-Optical/Infra-Red (EOIR) imaging system with capability to provide Kill Assessment (KA) and Raid Counting from an elevated position.

DESCRIPTION: Current U.S. Naval combat systems use onboard radar systems and processing for tracking, classification, and discrimination of incoming threat complexes. Threat complexes comprised of Closely Spaced Objects (CSOs) will fall within the resolution of onboard radar systems causing blind spots and preventing an accurate count of the number of threats present. Without an accurate count of inbound threats, the combat system must make choices on how to respond, which may be less than optimal and may not achieve raid annihilation. The same argument extends to KA after intercept, which is a critical time for the Combat System to make further engagement decisions. There is currently no known solution that will solve the blind spots issue.

Placing an off board EO/IR system at operationally relevant locations with respect to the ship will allow for the Ship Self-Defense System (SSDS) Combat System (CS) to observe incoming threats from a perspective which will address the stated KA and CSO blind spots. While it would be possible to gain some performance improvement on these KA and CSO concerns by upgrading the native radar systems, this would be time and cost prohibitive. Observing the incoming threat complexes and intercept points from a different aspect with commercial off-the-shelf (COTS) EO/IR sensors is desired to address performance and cost concerns.

By placing an EO/IR imaging capability at an operationally relevant elevation (to be determined in Phase I), inbound threat complexes could be observed from a different perspective than what is currently available to the shipboard sensors. The Navy seeks a system consisting of an EO/IR imaging capability with a mechanism to deliver it to a tactically useful off board position (to be determined in Phase I) to support self-defense engagement timelines. Current systems do not provide this capability. Selecting a platform capable of supporting not just an imaging capability but also computer hardware and software would allow for the development of a set of functions to observe inbound threats at pre- and post-intercept to supplement KA capabilities. Final system solution should satisfy testing requirements cited in Phase II. Solutions must cover both sub and supersonic Anti-Ship Cruise Missiles (ASCMs) and must meet or exceed current time to engagement timeline and SSDS CS survivability. The solution can consist of physical hardware, models and high-fidelity simulations, or a combination thereof. Any model and related simulation(s) used must be based on the detection parameters of EO/IR sensor(s) which are currently commercially available. The solution will be evaluated against scenarios provided by the sponsor. Provided scenarios will contain threat or threat surrogate information. Examples of desired detection capability would be Night Vision Integrated Performance Model (NV-IPM) developed by

## VERSION 8

Command, Control, Communications, Computers, Combat systems, Intelligence, Surveillance and Reconnaissance (C5ISR) Center's Night Vision and Electronic Sensors Directorate. Detection models of similar fidelity and capability will be acceptable. The solution used to demonstrate initial KA and Raid Counting algorithms may be based on synthetic data representative of selected sensor(s). Final delivered solution must also meet MIL-STD-810 for environmental conditions.

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

Phase III demonstration will allow for the opportunity to demonstrate the full solution capability against live scenarios of the same scope as those provided by sponsor during development phases. The solution developer will be responsible for providing any solution specific instrumentation and data collection necessary to prove the solution satisfies the criteria for success. SSDS system data will be made available for use in post-test analysis.

PHASE I: Develop a concept for an EO/IR imaging system with the capability to provide KA and Raid Counting from an elevated position. Demonstrate the feasibility of the concept to meet the described parameters listed in the Description through modeling, simulation, and analysis. Simulation results should be presented in the form of parameterized sweeps to demonstrate tactical regions of effectiveness and boundaries. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype of an EO/IR imaging system with the capability to provide KA and Raid Counting from an elevated position capable of stand-alone operation and a notional plan for integration into the SSDS CS. Demonstrate at a Government- or company-provided facility that the prototype meets all parameters presented in the Description. Final delivered solution must also meet MIL-STD-810 for environmental conditions.

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

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through system integration and qualification testing for the EO/IR prototype developed in Phase II. The EO/IR imaging system prototype will be delivered to support an IWS-10 critical experiment conducted jointly by the company and Combat System Engineering Agent (CSEA). This is expected to take place in a live environment with tactical SSDS CMS SW. Live fire test scenarios will be similar in scope to test scenarios provided by the sponsor during development phases. The transition will require integration of the prototype into SSDS CS.

Elevated EO/IR imaging system has applications in managing disaster relief efforts and addressing wildfires.

REFERENCES:

## VERSION 8

1. E. Blasch and B. Kahler, "Multiresolution EO/IR target tracking and identification," 2005 7th International Conference on Information Fusion, Philadelphia, PA, 2005, pp. 8 pp.-, doi: 10.1109/ICIF.2005.1591865.  
<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1591865>.
2. Bath, William G. "Overview of Platforms and Combat Systems", Johns Hopkins APL Technical Digest, Volume 25, Number 2 (2020) Integrated Air and Missile Defense,  
<https://www.jhuapl.edu/Content/techdigest/pdf/V35-N02/35-02-Bath.pdf>.

KEYWORDS: Electro-Optical/Infrared; EO/IR; Kill Assessment; KA; Raid Counting; Inbound Threats; Raid Annihilation; Detection models for incoming threats

## VERSION 8

N221-062 TITLE: Universal Environmental Controls for AM Machines

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

**OBJECTIVE:** Develop and demonstrate innovative technology to mitigate or eliminate environmental effects on Additive Manufacturing (AM) machines, as well as the effects AM machines have on their environment, through the use of modular controls that can be implemented as needed to augment Commercial-off-the-shelf (COTS) AM equipment for Navy use. This can be achieved by integrating COTS and or custom hardware into AM equipment to support Navy environments.

**DESCRIPTION:** The Navy develops specifications and standards for AM and the development of shipboard AM capabilities. The ability to produce components while at sea drastically reduces the burden on the supply and requisition systems while increasing platforms' abilities to complete missions. Currently, AM equipment suitable for afloat use is limited to small capacity, polymer-based, material extrusion systems. These systems were selected and integrated based on the fact that they are low cost, generally small, and easily integrated into existing platforms. These machines were installed to support the development of low risk, non-critical components in an effort to reduce supply chain burden and prove the concept of AM at sea. There are increased needs for AM afloat as explicitly mentioned in the NAVSEA Campaign Plan to Expand the Advantage 3.0 [Ref 1] as a technology focus area. This SBIR topic directly supports efforts to integrate AM into the Fleet and support a more self-sufficient ship. In addition, per the strategic document "A Design for Maintaining Maritime Superiority 2.0" [Ref 2] requires the Navy to maximize use of AM to fabricate "hard to source" or obsolete parts, reduce cost, field more effective systems, and reduce reliance on vulnerable supply chains through production at the point of need.

Currently, there is a need to mitigate or eliminate the environmental effect on AM machines and the effects AM machines have on their environment. The NAVSEA 05T AM Afloat program will benefit from a collection of equipment or systems that can be applied as standardized controls applicable to all polymer AM equipment. These controls will be installed/integrated to reduce safety and integration risks as well as increase use of AM equipment onboard Navy platforms and Shoreside facilities. As AM equipment is integrated in both afloat and shore based environments there is an increasing need for environmental controls to mitigate Shock, Vibration, ships motion, as well as temperature and humidity on AM machines. In addition, there is a need to mitigate Ultrafine Particles (UFPs) I.e. particles with a diameter < 100 nm, Volatile Organic Compounds (VOCs) emissions, EMI, and machine noise from AM equipment during operation. This topics is specifically interested in keeping machine noise below 85 decibels per OSHA standards [Ref 15].

The Navy environments, both Afloat and Shoreside, can have adverse effects on AM machines and their ability to produce parts consistently and accurately. The AM machines can also have adverse effects on their surrounding environment, which may impact nearby equipment or personnel, to include UFPs and VOCs emissions. Fortunately, control processes can be put in place to reduce and/or mitigate these risks. Such controls or mitigations vary based on AM process, machine type, and the environment they are installed in. As a result, these controls or mitigations must be modular or configurable to support a variety of scenarios. AM machines are not currently developed with the Navy in mind and therefore do not meet military standards or have environmental controls in place from the Original Equipment Manufacturer (OEM). However, due to the rate at which technology changes, it is not feasible to expect every AM machine to meet military standards. It is more sustainable for AM machines to use modular controls that can be implemented as needed to augment COTS AM equipment for Navy use. In addition, standardized filtration systems for polymer AM equipment is either non-existent, or relies on filtration technology with



## VERSION 8

little modeling and simulation to ensure the filters are adequately removing the UFP and VOC emissions produced by the AM equipment. In many cases, High-Efficiency Particulate Absorbing (HEPA) filters sufficiently capture the UFPs emissions. Unfortunately, ensuring the UFPs actually make it to the HEPA filters is where there is significant uncertainty. As this equipment becomes more prevalent shipboard, UFP and VOC emissions control will become paramount to ensure the safety of the crew when using these machines. Furthermore, the standards and baselines by which the equipment is tested are currently in the early stages of research, and a better understanding of the requirements for filtration and duration of filtration must also be investigated. Additionally, AM equipment may cause electromagnetic interference (EMI) or acoustic issues while onboard Navy platforms.

These machines and the controls applied will be tested at Navy facilities or by Government contractors who are certified to test at the Mil Standards listed below. In addition, the controls will be tested on multiple machine types determined by the Navy based on applicability. Prototype solutions delivered to the Government for shipboard integration testing must comply with all MIL-STDs in the references section of this topic. The solutions delivered to the Government must include all applicable equipment to be tested. For example, if the mitigation solution is physically attached to a piece of AM equipment, the solution must also include the AM equipment to be tested.

MIL-STDs tested against:

- MIL-S-901D, Amended with Interim Change #2, Shock Test, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for
- MIL-STD-167-1, Mechanical Vibration for Shipboard Equipment (Type I - Environmental and Type II - Internally Excited)
- MIL-STD-461F, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
- MIL-STD-740-2, Structure-borne Vibration Acceleration Measurements and Acceptance Criteria of Shipboard Equipment
- UL 2904, ANSI/CAN/UL Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers
- MIL-STD 810, Environmental Engineering Considerations and Laboratory Tests

**PHASE I:** Define and develop a conceptual system capable of environmental control/mitigation that is tailorable to the integration scenario (shipboard, expeditionary, or maintenance/shop environment). Formulate supportive modeling and simulations for feasibility and verification. Develop notional Computer Aided Design (CAD) designs (as appropriate), bill of materials, and build plans, to support the conceptual system. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Using the deliverables from Phase I, produce and deliver four (4) functional prototypes of environmental controls to be tested. These Prototypes must be modular and/or tailorable to support integration of AM equipment into shipboard (surface/undersea), expeditionary, or maintenance environments. Include a sensor suite capable of determining various environmental conditions and printer-induced environmental impacts (VOCs, UFPs, etc.). Provide integration plans, initial installation, operational, and maintenance documentation to support prototype systems. Provide test and verification data indicating that controls properly mitigate or eliminate environmental effects on AM machines as well as effects AM machines have on their environment.

**PHASE III DUAL USE APPLICATIONS:** Stand up a production line of tailorable, physical environmental controls to support the integration of AM equipment into shipboard, expeditionary, and maintenance environments with a minimum production run that is able to support existing shipboard equipment at the time of Phase II completion. Provide the ability to test and validate environmental

## VERSION 8

effects caused by shipboard AM equipment and mitigation solutions. Offer the expanded development of an environmental standard for mitigation requirements in the shipboard environment. The ability to tailor controls for different machines and different environments will enable NAVSEA 05T to safely and rapidly integrate AM equipment on Navy platforms and Shoreside. This capability will ultimately support the Navy's adoption of AM across the fleet and into the future as technology evolves to support just in time delivery of components necessary to complete the mission. The solution(s) developed under this SBIR topic could transition to various industries leveraging polymer AM in their business. Filtration of the UPFs and VOC emission will be a commercially marketable product not specific to DON requirements. In addition, the environmental mitigation controls implemented could transition to other DOD or commercial entities operating in fluctuating or dynamic environments that require control of the temperature and humidity of the AM platform. Since development of this solution(s) is around COTS equipment, AM OEMs may also be interested in the technology developed.

### REFERENCES:

1. "NAVSEA Campaign Plan to Expand the Advantage 3.0."  
[https://www.navsea.navy.mil/Portals/103/Documents/Strategic%20Documents/NAVSEA\\_CampaignPlan3.0-Jan2021.pdf](https://www.navsea.navy.mil/Portals/103/Documents/Strategic%20Documents/NAVSEA_CampaignPlan3.0-Jan2021.pdf).
2. Richardson, John ADM. "A Design for Maintaining Maritime Superiority 2.0." December 17, 2018. <https://news.usni.org/2018/12/17/design-maintaining-maritime-superiority-2-0>.
3. Watson, J. Throck & Sparkman, O. David. "Introduction to Mass Spectrometry: Instrumentation, Applications, and Strategies for Data Interpretation, 4th Ed." Chichester: John Wiley & Sons, 2007.
4. Werle, P., Slemr, F., Maurer, K., Kormann, R., Mucke, R. and Janker, B. "Near- and Mid-Infrared Laser-Optical Sensors for Gas Analysis." *Opt. Las. Eng.* 37(2-3), 101-114 (2002).  
[https://www.researchgate.net/profile/Franz\\_Slemr/publication/228543356\\_Near-and\\_mid-infrared\\_laser-optical\\_sensors\\_for\\_gas\\_analysis/links/5681672208ae1975838f86d4.pdf](https://www.researchgate.net/profile/Franz_Slemr/publication/228543356_Near-and_mid-infrared_laser-optical_sensors_for_gas_analysis/links/5681672208ae1975838f86d4.pdf).
5. "Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants." Washington, DC: The National Academies Press, 2007.  
<https://www.nap.edu/catalog/11170/emergency-and-continuous-exposure-guidance-levels-for-selected-submarine-contaminants>.
6. "Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants: Volume 2." Washington, DC: The National Academies Press, 2008.  
<https://www.nap.edu/catalog/12032/emergency-and-continuous-exposure-guidance-levels-for-selected-submarine-contaminants>.
7. "Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants: Volume 3." Washington, DC: The National Academies Press, 2009.  
<https://www.nap.edu/catalog/12741/emergency-and-continuous-exposure-guidance-levels-for-selected-submarine-contaminants>.
8. "MIL-S-901D, Amended with Interim Change #2, Shock Test, H.I. (High Impact); Shipboard Machinery, Equipment and Systems, Requirements for."
9. "MIL-STD-167-1, Mechanical Vibration for Shipboard Equipment (Type I - Environmental and Type II - Internally Excited)"
10. "MIL-STD-461F, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment."
11. "MIL-STD-740-2, Structure-borne Vibration Acceleration Measurements and Acceptance Criteria of Shipboard Equipment."
12. "UL 2904, ANSI/CAN/UL Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers."
13. "MIL-STD 810, Environmental Engineering Considerations and Laboratory Tests."
14. Donaldson K, Stone V, Clouter A, et al. Ultrafine particles. *Occupational and Environmental Medicine* 2001;58:211-216

## VERSION 8

15. “Department of Labor Logo United Statesdepartment of Labor.” Occupational Noise Exposure - Overview | Occupational Safety and Health Administration, [www.osha.gov/noise](http://www.osha.gov/noise).

KEYWORDS: Additive Manufacturing; Volatile Organic Compounds; Ultrafine Particles; UFP; Volatile Organic Compounds; VOC; Environmental Controls; Atmospheric Monitoring; Shipboard Motion

## VERSION 8

N221-063 TITLE: Nonlinear Mitigated Gain Fiber Development for kW-class Fiber Lasers

OUSD (R&E) MODERNIZATION PRIORITY: Directed Energy (DE)

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 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 Stimulated Brillouin Scattering (SBS) mitigated rare-earth-doped fibers supporting the advancement of narrow-linewidth kW-class fiber amplifiers essential for future high-energy laser (HEL) weapons integration with reduced cost and power scalability.

**DESCRIPTION:** The rapid development and deployment of HEL systems have enabled laser weapons in different platforms for DoD's applications. Kilowatt (kW)-class single-mode fiber lasers have been the key engines for these HEL systems because of their inherent advantages including excellent beam quality, outstanding heat dissipation capability, high single-pass gain, hermetically guided laser beam, and high-power scalability. There is high demand for kW-class fiber amplifiers for narrow-linewidth HELs that are required for specific applications. However, kW-class fiber amplifiers always suffer from SBS, RAMAN scattering, and other nonlinear effects such as four-wave mixing (FWM), self-phase modulation (SPM), and stimulated RAMAN scattering (SRS), etc. Although several types of large-mode-area (LMA) fibers have been fabricated and used to demonstrate kW-class fiber amplifiers with mitigated nonlinear Kerr effects and SRS, SBS is still a major constraint on the power scaling of kW-class fiber amplifiers for narrow-linewidth lasers. Therefore, innovative rare-earth-doped fibers with mitigated SBS and other nonlinear effects are crucial for the development of narrow-linewidth kW-class fiber amplifiers. The U.S. Navy is searching for an innovative nonlinear mitigation kW class rare-earth doped fiber at 1 to 2  $\mu\text{m}$  wavelength. Current commercially available kW class amplifier power is limited to approximately 2 kW per amplifier. This SBIR topic seeks innovative technology to increase the HEL SM (Single mode) narrow line width amplifier to approximately 4 kW. This topic seeks design, development, and fabrication of > 6 kW-class rare-earth optical fiber. Commercial state of the technology is only around 2 kW per amplifier due to SBS.

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

**PHASE I:** Develop a concept and demonstrate the feasibility of that concept to meet the Navy's requirements as outlined in the Description. Demonstrate the power scalability of the new single mode

## VERSION 8

SBS reduced optical fibers for narrow-linewidth laser amplification. Provide the design of kW-level fiber amplifiers and show path to reaching 6-kW laser output without mitigated SBS and other nonlinear effect. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Under Phase II base period develop the SBS reduced fiber that can meet the Navy requirements and in Phase II Option I use this type of SBS reduced doped fiber for > 5kW class amplifier design and demonstrate the performance to the Navy. And in Phase II deliver a prototype system for testing and evaluation based on the results of the Phase II base and Option I. Phase II Option II, deliver SBS reduced doped fiber > 200 meter to the Navy for the final evaluation done at a Navy lab. Results shall be used to optimize the design, modeling and fabrication of the rare-earth-doped optical fibers and provide a fiber amplifier prototype that can be used to achieve 6-kW narrow-linewidth (< 0.5 nm) laser at – 1 micro meter, 1.5 micro meter and 2 micro meter.

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. Advanced rare-earth doped optical fibers with mitigated SBS and other nonlinear effects can be used in various HEL weapon systems for DoD applications, DOE's accelerator lasers, the laser sources for free-space communication, kW class optical power delivery over > 300 meter, and remote sensing systems.

For commercial and industrial application; this technology could produce compact, efficient, kW class HEL systems for industrial material processing applications such as welding, cutting, soldering, marking, cleaning, etc., in the automotive and aerospace industries.

### REFERENCES:

1. T. T. Alkeskjold, M. Laurila, L. Scolari, and J. Broeng, "Single-mode ytterbium-doped large-mode-area photonic bandgap rod fiber amplifier", *Opt. Express* 19 (8), 7398 (2011).
2. L. Dong et al., "Leakage channel optical fibers with large effective area", *J. Opt. Soc. Am. B* 24 (8), 1689 (2007).
3. D. Jain et al., "Demonstration of ultra-low NA rare-earth doped step index fiber for applications in high power fiber lasers", *Opt. Express* 23 (6), 7407 (2015).
4. F. Beier et al., "Narrow linewidth, single mode 3 kW average power from a directly diode pumped ytterbium-doped low NA fiber amplifier", *Opt. Express* 24 (6), 6011 (2016).
5. J. Olson, et al, "3 mJ All-Fiber MOPA With a Short-Length Highly Er<sup>3+</sup>-Doped Phosphate Fiber," *IEEE Photon. Technol. Lett.* 32 (23), 1481 (2020).

KEYWORDS: Stimulated Brillouin scattering; SBS; RAMAN scattering mitigation; Rare-earth-doped fibers; kW-class fiber lasers; Nonlinear effects; Large-mode-area fibers

## VERSION 8

N221-064 TITLE: Medium Voltage Direct Current Disconnect Switches

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Ground / Sea Vehicles

OBJECTIVE: Develop a family of disconnect switches and associated switchgear enclosures for 12 kV Medium Voltage Direct Current (MVDC) electrical distribution systems for naval combatant applications.

DESCRIPTION: Integrated Power and Energy System (IPES) offers the potential to provide revolutionary warfighting capability at an affordable cost. IPES utilizes integrated energy storage and power along with advanced controls to provide a distribution bus suitable for servicing highly dynamic mission loads and propulsion demands while keeping the lights on. Additionally, such a system can enhance survivability, reliability, and flexibility while providing new capabilities, such as the ability to quietly maneuver solely on energy storage. IPES development is focused on a Medium Voltage Direct Current (MVDC) system evolved from the DDG 1000 1kVDC Integrated-Fight-Through-Power system, combined with shared and distributed energy storage as well as advanced controls with active state anticipation data linkage between machinery and combat systems. As threat capabilities improve over the coming decades, the Navy anticipates a heavy reliance on high power, highly dynamic, pulsed weapons and sensors. Because the need for generator synchronism is eliminated, MVDC is anticipated to be able to support these systems at lower cost, lower weight, and lower space requirements. Details on IPES are provided in the Naval Power & Energy Systems (NPES) Technology Development Roadmap [Ref 1].

One of the key enablers of an MVDC IPES is a reliable means for MVDC equipment isolation to conduct maintenance and fault isolation on the MVDC bus. Disconnect switches, in conjunction with appropriate protection relays, offer the opportunity to fulfill these functions at a lower size, weight, and cost than MVDC circuit breakers. MVDC disconnect switches and associated switchgear are enablers for affordable naval power and energy systems to support multiple future high power, pulsed sensors, and weapons on future surface combatants. Commercial or military MVDC disconnect switches and associated switchgear are not currently manufactured by any company. More information on MVDC Fault Detection, Localization and Isolation can be found in Doerry and Amy [Ref 2].

The objective of this SBIR topic is to develop a family of MVDC two pole disconnect switches and associated switchgear for 12 kV MVDC distribution systems on naval ships with continuous current ratings ranging from 100 amps to 3,500 amps (threshold) and 4,000 amps (objective). The challenge will be to develop affordable, power dense disconnect switches suitable for naval surface ship applications that can be locally or remotely controlled and can be opened or closed within 50 milliseconds (ms) (threshold) or 10 ms (objective). The disconnect switches shall be capable of interrupting at least 2% (threshold) or 100% (objective) of the rated current. The disconnect switches shall have a design life of 30 years (threshold) or 50 years (objective) and be capable of up to 10,000 switch operations (threshold) or 20,000 switch operations (objective). The disconnect switches shall be compatible with 12 kV power as detailed in the Preliminary Interface Standard, Medium Voltage Electric Power, Direct Current [Ref 3]. The steady-state efficiency of the disconnect switch shall be greater than 99.98% (threshold) or 99.99% (objective).

The switchgear enclosure for the disconnect switches should be modular to enable custom configurations of disconnect switches based on the sources and loads within a zone. The switchgear should minimize weight and maximize power density. For a single 2,000 amp two pole disconnect switch, the associated switchgear module shall have a power density greater than 20 MW/m<sup>3</sup> (threshold) or 50 MW/m<sup>3</sup> (objective) and shall weigh (including the disconnect switch) no more than 1,200 kg (threshold) or 200 kg (objective). The switchgear should be deck mounted (threshold) or bulkhead mounted (objective) while

## VERSION 8

still meeting Grade A shock requirements. The switchgear should be air cooled. The switchgear should be capable of being integrated with MVDC cables or with MVDC insulated bus pipe. All repair parts should fit through standard shipboard hatches. The contractor shall demonstrate through testing in their own facilities the ability of the switchgear and disconnect switches to achieve the design ratings.

These MVDC disconnect switches are anticipated to have commercial applications as MVDC systems are increasingly employed in micro grids, offshore wind, cruise ships, and solar power installations.

PHASE I: Develop initial design concepts for the disconnect switches and associated switchgear for the complete family of disconnect switches. Establish the standard disconnect ratings comprising the family based on minimizing cost and size of switchgear for shipboard applications. Conduct electrical, mechanical, and thermal dynamic simulations to demonstrate the feasibility of the design. Assess risks associated with the design and develop mitigation plans. Risks not requiring physical testing of the prototype shall be addressed in the Phase I option.

In the Phase I option, if exercised, develop test plans that include risk mitigation requiring physical testing of the prototype for Phase II. Develop interface descriptions and performance data for the disconnect switches and associated switchgear necessary for successful integration into a shipboard power system.

PHASE II: Develop, test, and deliver to the Navy prototype switchgear and installed prototype disconnect switches in accordance with the draft specifications developed in Phase I or an update to the draft specification. The ratings of the prototype disconnect switches and the configuration of the prototype switchgear shall be chosen to maximize learning and risk mitigation. Demonstrate through testing in their own facilities the ability of the switchgear and disconnect switches to achieve the design ratings. Validate or update simulations from Phase I based on test results. Deliver to the Navy an update to the interface descriptions and performance data and develop design guidance for configuring and integrating the disconnect switches and associated switchgear into an MVDC power system design.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. The MVDC disconnect switch and associated switchgear are planned to be incorporated into a future surface combatant to support high power and pulsed power weapon systems. Commercial applications may include cruise ships, offshore platforms, wind farms, and solar farms. Produce and test production representative disconnect switches and associated switchgear enclosures in accordance with the Phase III SOW. These production representative disconnect switches and associated switchgear shall be delivered to the Navy for integration into a test system to evaluate the disconnects and switchgear for application in a future surface combatant. Deliver to the Navy an update to the design guidance from Phase II, an update to the simulation models (as required), a maintenance manual, and user training material.

### REFERENCES:

1. Naval Sea Systems Command, "Naval Power & Energy Systems (NPES) Technology Development Roadmap" 2019 <https://www.navsea.navy.mil/Resources/NPES-Tech-Development-Roadmap/>.
2. Doerry, Dr. Norbert and Dr. John V. Amy Jr., "Design Considerations for a Reference MVDC Power System," presented at SNAME Maritime Convention 2016, Bellevue, WA, Nov 1-5, 2016. <http://doerry.org/norbert/papers/20160805-Design-considerations-for-a-Reference-MVDC-Power-System.pdf>.
3. Doerry, Norbert, "Preliminary Interface Standard, Medium Voltage Electric Power, Direct Current," Naval Sea Systems Command, Technology Office (SEA 05T), Ser 05T/002 of 16 January 2020. <https://apps.dtic.mil/sti/pdfs/AD1090170.pdf>.

## **VERSION 8**

**KEYWORDS:** Medium Voltage Direct Current; MVDC Disconnect switch; Switchgear; MVDC Equipment Isolation; MVDC Distribution System; MVDC Bus; MVDC Fault Isolation



## VERSION 8

N221-065 TITLE: Low Cost, Small Form Factor Scalable Receive Array

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 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: Apply innovative technology to develop a five-band compact Modular Expansive Spectrum Passive Receiver (MESPR) to address gaps in fielding passive sensor recognition and countermeasure algorithms.

DESCRIPTION: Navy surface ship and submarine probability of survival improves when protected by torpedo defense countermeasure systems. Adversarial weapons are increasing sophistication that requires the Navy to rapidly implement and integrate pace-the-threat technology via the Navy's Technical Insertion/Advanced Processor Build (TI/ABP) process. Traditional receivers perform at a purposed frequency band of specific interest. Legacy system architectures typically do not easily support technology insertions. The Navy has invested in system updates for cost-effective technology insertions. MESPR would directly benefit Surface Ship Torpedo Defensive (SSTD) and submarine torpedo defense programs. MESPR addresses the need to counter technology improvements inherent in threat torpedoes. The innovative technology could be dual purposed to enhance or replace unmanned undersea vehicle (UUV) and torpedo sensor suites. The expansive spectrum is comprised of the Super Low Frequency (SLF), Ultra Low Frequency (ULF), Very Low Frequency (VLF), Low Frequency (LF), and Medium Frequency (MF) frequency bands as designated by the International Telecommunications Union (ITU) for radio spectrum designators and bandwidths to include:

- SLF: 30 Hz-300 Hz
- ULF : 300 Hz-3 kHz
- VLF: 3K Hz-30K Hz
- LF: 30K Hz to 300K Hz
- MF: 300K Hz to 3,000K Hz

A technology challenge will be to implement MESPR using traditional and non-traditional materials and hardware to achieve efficient transduction across the defined bandwidth. A second technology challenge addresses complex issues related to spectrum detection and correlation across a five-band receiver. A third technology challenge defines a prototype capable of performing while a local host is transmitting broadband and structured energy. To decrease technical risk for modularity and Space, Weight and Power (SWaP), improvements can be incrementally addressed as Phase II and Phase III activities progress. The SWaP of the MESPR prototype must be developed for technology insertion within three inch, four inch, and six inches countermeasure systems. Operational depth of the MESPR is up to 2,000 feet below ocean surface. The MESPR concept must include passive sensor and sensor configurations for sensitive detection with high dynamic range, dynamic array gain, volumetric localization, and beam steering. Traditional and non-traditional sensor and mechanical model and simulation analysis will support the proposed concept to meet the requirements in this Description. Modeling and simulation will address receive sensor and detection degradation caused by flow noise, local coherent signals and interferers. A

## VERSION 8

variety of torpedo defense land-based and at-sea demonstrations may be utilized to assess technology performance and viability.

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

PHASE I: Define and identify a feasible concept for the innovative MESPR prototype to demonstrate performance, modularity, and SWaP constraints. Identify candidate sensor and hardware culminating in a modular and compact design approach. Perform modeling and simulation to provide initial assessments of performance and SWaP limitations. Incorporate a Transmission Control Protocol/Internet Protocol (TCP/IP) electrical to optical Ethernet interface for receipt of command-and-control messages while sending MESPR raw and processed sensor data and hardware status. The development approach will address how compact processing and programmable logic are utilized to locally process sensor receive data. Intelligent hardware must have features to meet Cybersecurity and data protection requirements. Commercial Off-The-Shelf (COTS) components must be in production currently and planned to be in production for a minimum of three years. A hardware obsolescence approach must be addressed in Phase I. Develop a risk adverse approach to incrementally demonstrate MESPR performance, modularity, and cost management. The Phase I Option, if exercised, will include the initial layout and capabilities description to implement the concept and approach in Phase II. A final Phase I report for this SBIR effort will identify an innovative and feasible approach for Phase II to demonstrate working prototypes. A schedule will be provided to identify key Phase I and Phase II component and MESPR technology milestones.

PHASE II: Develop the MESPR prototype based on Phase I modeling and analysis, Establish performance parameters through continued modeling, sensor, and hardware experimentation. Construct and demonstrate an operational prototype. Perform performance and environmental evaluation testing of the MESPR prototypes based on the derived performance parameters. Testing will be the responsibility of the executing company, to include static and dynamic testing to assess utility for passive receive sensitivity and directionality across the MESPR band of interest. A functional prototype will be demonstrated in a relevant environment at a Navy facility such as the Naval Undersea Warfare Center (NUWC) Seneca Lake Sonar Test Facility. A prototype will demonstrate temperature thermal cycling, Grade A shock, vibration analysis and cyber resilience. Prepare a technical description document and user guide. Update the schedule prepared in Phase I to identify key Phase II and Phase III technology milestones. Deliver three to five working prototypes for further assessment by the Government. In support of Phase II prototype development and Phase III technology transition, the Navy will identify specific torpedo defense hardware targeted for MESPR integration, test, and demonstration.

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

PHASE III DUAL USE APPLICATIONS: Integrate the Phase II delivered MESPR prototypes with Government identified torpedo defense hardware. Identify incremental technology improvements to achieve end goals. Demonstrate MESPR technology improvements through planned prototype updates

## VERSION 8

using lessons learned in Phase II and Phase III. Demonstrate the MESPR technology can be inserted and interoperable with torpedo defensive countermeasures to achieve performance and SWaP objectives. Evaluate three to four Phase III final prototypes for delivery. Support at-sea demonstration from a U.S. Navy platform to assist evaluation of the design in a relevant environment. Technical and logistic documentation will be developed to support technology transition to a PMS415 program of record. The schedule prepared in Phase II will be updated to identify key Phase III component technological milestones and will include a 12-to-24-month technology transition schedule.

A Commercial application of MESPR could support a producer of Autonomous Undersea Vehicles (AUVs). As an example, an AUV could search for a black box from a downed airplane.

### REFERENCES:

1. Burdic, William S. "Underwater Acoustic System Analysis." Prentice Hall, Englewood Cliffs, New Jersey, 1991. <https://asa.scitation.org/doi/abs/10.1121/1.391242>.
2. Butler John L. and Sherman Charles H. "Transducers and Arrays for Underwater Sound." Springer International Publishing, Switzerland, 2016.
3. Brown, Jeremy, A. "Fabrication and performance of a single-crystal lead magnesium niobate-lead titanate cylindrical hydrophone." The Journal of the Acoustical Society of America 134, ; <https://doi.org/10.1121/1.4812274>.
4. Abdul, Basit. Mastronardi Vincenzo M. and others. "Sensitivity and Directivity Analysis of Piezoelectric Ultrasonic Cantilever-Based MEMS Hydrophone for Underwater Applications." Journal of Marine Science and Engineering, 9 October 2020.
5. Eovino, Benjamin T. "Design and Analysis of a PVDF Acoustic Transducer Towards an Imager for Mobile Underwater Sensor Networks." Electrical Engineering and Computer Sciences University of California at Berkeley. Technical Report No. UCB/EECS-2015-154, <http://www.eecs.berkeley.edu/Pubs/TechRpts/2015/EECS-2015-154.html> May 26, 2015.

**KEYWORDS:** Undersea defensive systems; acoustics; non-traditional sensor materials; sonar signal processing; signal detection; signal localization

## VERSION 8

N221-066 TITLE: New Water-Blocking Chemicals/Materials for Zero Longitudinal Seawater Flow through Navy Outboard Cables

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop new outboard cable water-blocking chemicals/materials system that prevent the longitudinal movement of seawater through a cable after the watertight integrity of the cable jacket or connector is breached (thereby allowing seawater to enter the interior of the cable).

DESCRIPTION: When the watertight integrity of an outboard cable is breached, the navy depends upon a water-blocking compound within the interior of the cable to slow/prevent the movement of seawater down the length of the cable. Seawater moving through the interior of a cable will eventually reach either end where it will come in contact with sensors, power supplies, and other electrical components and connectors. This often results in extensive and costly damage to these crucial pieces of equipment and could trigger system failures that can compromise the ability of Navy ships and submarines to perform their assigned missions.

The objective is to develop new saltwater-blocking materials that will prevent the longitudinal movement of seawater through the interior of a breached/flooded outboard cable both at high (500 - 1000 psi) and low (25 psi) hydrostatic pressure conditions. The governing military specification for outboard cables (MIL-DTL-915G; reference 1) contains two water-blocking requirements: section 4.5.12 (hydrostatic/open end – high pressure) and section 4.5.17 (water tightness - low pressure). Although reference 1 allows some water flow through the interior of cables undergoing these tests, the goal of this SBIR topic is to develop a water-blocking chemical/material system that prevents any saltwater from flowing through the cable segments used in these tests. Commonly used Navy outboard cable jacket materials include polychloroprene, polyurethane, poly (vinyl chloride), and chlorosulfonated polyethylene. The water-blocking chemical/material in a non-compromised/flooded cable must allow individual conductors within the cable to be easily accessed and separated from other conductors/wires.

The chemical composition of the most commonly used water-blocking materials used in outboard cables is unknown to the Navy. The material is soft and rubbery and typically performs acceptably during the MIL-DTG-915G hydrostatic/open end test. We believe it is successful because the high hydrostatic pressure allows the formation of a compression seal with the water-blocking compound. It typically allows some water to pass through the interior of the cable during the MIL-DTG-915G water tightness test (presumably because the much lower hydrostatic pressure is not sufficient to form a pressure seal). For the purposes of this SBIR topic, the Navy will not forbid or restrict the use of any particular materials/chemistries for the new water-blocking material, but materials of low toxicity and environmental impact are preferred over those of high toxicity and environmental impact. New water-blocking materials may utilize non-reversible chemistries as long as the longitudinal flow of saltwater is prevented (proposers may assume the breached cable will be scrapped/never used again upon return of the vessel to port); the goal is to protect the equipment attached to the ends of the cable. The Navy notes that it has tested super water absorbent gels (e.g., sodium polyacrylate) as a possible candidate for a new/improved cable water-blocking material. However, the results were disappointing since the absorption of water by such materials is impeded by the presence of dissolved ions in the water, so this material does not work well with seawater. The Navy will consider modified versions of super water absorbent gels that have been modified to work acceptably (per the MIL-DTL-915G requirements) with seawater. For example, the new water-blocking material could be a polymer system that reacts irreversibly with seawater to form a water-block; however, the material should be designed to react with seawater flooding a cable, but not with water diffusing through the cable jacket. The

## VERSION 8

flexibility/bendability of the affected cable need not be retained once the water blocking reaction is triggered.

Major goals/considerations for this SBIR topic:

The new water-blocking chemical/material MUST:

1. Work with SEAWATER.
2. PREVENT/STOP the longitudinal flow of seawater through a cable at both high (up to 1000 psi) and low (25 psi) hydrostatic pressures.
3. NOT be triggered by (fresh) water diffusing through the cable's outer jacket.
4. BE COMPATIBLE WITH the outboard cable manufacturing process
5. Have as low an ENVIRONMENTAL and TOXICITY impact as possible

PHASE I: Define and develop a concept for innovative water-blocking materials/chemistries that could be used inside Navy outboard cables to prevent saltwater from flowing longitudinally through such cables. "Simulated cables" (rubber tubes filled with the proposed water-blocking material) may be used to demonstrate proof of concept. During phase I, the emphasis should be on the chemistry of water-blocking material. The proposer will be expected to contact cable manufacturers to verify that the proposed chemistries would be compatible with commonly used cable manufacturing processes. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop and deliver a prototype of at least three different types of navy outboard cables of sufficient length to be tested for hydrostatic pressure/open face and water tightness in accordance with a modified version of the MIL-DTF-915G tests that will substitute seawater for freshwater. Both kinds of hydrostatic testing shall be conducted and no passage of seawater through the cables should occur. Refinement of the water-blocking chemistry/material will be conducted, as necessary. The new water-block chemical/material will be tested with the commonly used cable jacket materials noted in the "description" section.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use through one or more commercial cable manufacturers to incorporate the new water-blocking material/technology into operational Navy outboard cables used by the sponsoring Navy Program Office. Work with the Navy to obtain approval for Navy use of such cables by the appropriate Navy authority.

Potential employment for this technology in the private sector is good. Outboard submerged cables can be found on civilian ships, submarines, and unmanned undersea vehicles. Additionally, this cable technology has use on submerged civilian marine infrastructure such as seabed power and communication cables.

### REFERENCES:

1. MIL-DTL-915G, "Detail Specification: Cable, Electrical, for Shipboard Use, General Specification for," 22 August 2002. (Note: This document has been approved for public release; distribution is unlimited).
2. Worzyk, T, Submarine Power Cables: Design, Installation, Repair and Environmental Aspects, Springer Science and Business Media, 2009, 296 pp.
3. Powers, W. F., "An Overview of Water-Resistant Cable Designs," IEEE Transactions on Industry Applications, 29, 5, 831, (1993), doi: 10.1109/28.245702  
<https://ieeexplore.ieee.org/document/244196>.
4. Ma, X., and Wen, G., "Development History and Synthesis of Superabsorbent Polymers: A Review," J. Polym. Res., 27, 136, (2020), doi: 10.1007/S 10965-20-02097-2  
<https://link.springer.com/article/10.1007/s10965-20-02097-2>.

## **VERSION 8**

**KEYWORDS:** Underwater Cables; Hydrostatic Pressure; Water-blocking; Water-Proofing; Water-Tightness Testing; Super-Absorbent Polymers.

## VERSION 8

N221-067      **TITLE:** Improved Reliability of Composites Pi-Joints for use in Primary Aircraft Structures

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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:** Improve reliability, reduce uncertainty and scatter in performance and hence enhance the user communities' confidence in the use of pi-preform-based primary bonded composite structures.

**DESCRIPTION:** While the robustness and load-carrying capability of pi-joint based primary bonded structures have been demonstrated in past development programs [Ref 1], the joining technology is not widely used. Fabricated joints still show variable porosity and resin-pooling [Ref 2]. This in turn provides a large scatter in failure strength. Repeatability of the process remains an issue. This uncertainty hinders characterizing the bondline of as-built geometry and subsequent use of analysis techniques to prognosticate structural performance.

There can be multiple approaches to address this topic:

1. Interface improvement by using film resins that are currently being developed [Ref 2]. Additionally, interface toughening with nano-additives shows promise in providing more control on the interface and reducing the scatter.
2. A method to efficiently create a digital twin of the fabricated joint in the as-built condition using X-Ray/ Ultrasonic (UT)/ or Computed Tomography (CT) can be a solution [Ref 3]. Such digital twin can be used to develop high fidelity models to predict failure. The accumulated digital data can also be used to develop a database of critical joints that can be used with big-data algorithms to extend building block testing.
3. A sensor based Non-destructive Inspection (NDI) system that can monitor cure directly or indirectly. These sensors can also be potentially used during service life of the part for health monitoring system.

The above are suggestions only – any viable method to improve pi-joint reliability will be responsive to the SBIR topic. Additionally, the robustness, manufacturability, maintainability, and affordability of the proposed technology will be important consideration in the selection process.

**PHASE I:** Focus on establishing feasibility of a proposed concept via a flat panel with a single stringer attached by a pi-joint. The joint should be able to transfer shear, tension, compression, and torsion. Proof of concept testing will be at lab scale to establish joint allowable and associated scatter in data. Additionally the effectiveness of any sensors used for cure monitoring has to be established. Preliminary scale up plans have to be established in this Phase.

**PHASE II:** Mature and demonstrate the methods developed in Phase I. Further develop and optimize the pi-joint through testing a relevantly-sized, fixed wing or rotorcraft-representative skin-to-frame joint to

## VERSION 8

demonstrate the reliability, durability, inspectability, maintainability, weight efficiency, and affordability of the method. Models to predict performance and inform design choices of the joint shall be developed and verified/validated using the test data. Potential use of any sensors used for health monitoring will need to be planned. A study to assess the maintenance and cost requirements shall be performed in preparation for Phase III.

PHASE III DUAL USE APPLICATIONS: Further mature and commercialize the novel and reliable pi-joint for composite skin-to-frame connection and load transfer. Consideration shall be given to improving manufacturing readiness level and airworthiness qualification through modeling and testing with a vision toward reliable, durable, inspectable, maintainable, lightweight, and affordable joints that will ease their insertion in both manned and autonomous platforms.

Lightweight fastener free joints are as attractive to the commercial sector as it is for the military. This is especially true in the vibrant Urban Air Mobility Sector. Additionally, composites are increasingly used in high end automobiles, especially in electric vehicles.

### REFERENCES:

1. Russell, John D. "Composites Affordability Initiative. Transitioning Advanced Aerospace Technologies through Cost and Risk Reduction", AMMTIAC Quarterly, Vol 1, No 3. Pp 3-6, 2006,
2. Ghomi, N. "Secondary Bonded Pi-Joint Out of Autoclave Process." Master's Thesis, McGill University, Montreal, PQ, 2013. <https://escholarship.mcgill.ca/downloads/k930c1599>.
3. Seon, G.; Shonkwiler, B. and Makeev, A. "Predicting Defect Formation at Early Stages of Manufacturing Process." American Society for Composites 34th Technical Conference, September 23-25, 2019, Atlanta, Georgia. <http://dpi-proceedings.com/index.php/asc34/article/view/31433>.
4. Torre-Poza, A. et. al. "Challenges of complex monitoring of the curing parameters in coupons for LRI manufacturing." INCAS Bulletin; Bucharest, Vol 13, Issue 1, 2021, pp. 201-210. <https://www.proquest.com/openview/2733066f6b4e14af22cbd529438051e8/1?pq-origsite=gscholar&cbl=2029115>.

KEYWORDS: Composites pi-joint; bonded joint; skin-stringer joint; toughened adhesive; in-situ cure monitoring; health monitoring



## VERSION 8

N221-068 TITLE: DIGITAL ENGINEERING - Requirements Management Tool for Design of Effective Human Machine Systems with Evolving Technologies

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML);Autonomy;General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Human Systems;Information Systems

OBJECTIVE: Develop an interactive environment that allows all stakeholders in the Acquisition lifecycle to participate in the design of a 'platform' using a set of tools and supporting methodology for systematically capturing requirements and decisions made for the human components of complex human-machine systems from initial system conception, through systems design, and on into systems acquisition and deployment.

DESCRIPTION: Mismatches between system requirements and human operator capabilities are a recurring problem that are being exacerbated by the rapid evolution of automation & "smart" technologies [Ref 1]. Design and acquisition of Naval systems cannot anticipate the capabilities on the near and far term horizons. Deciding which functions (tasks, jobs) of a human-machine system should be allocated to the human and which to the machine (typically a computer) is one of the most essential activities within human factors research [Refs 2-4]. A new approach to managing human requirements and matching them to technical capabilities throughout the development and acquisition process is needed. A system is needed that captures and documents those functions and capabilities that are determined to be fundamentally human and they must be documented and tracked throughout the system design and acquisition process.

This SBIR topic seeks innovative approaches to identify, document and systematically track those task functions and capabilities that are assigned to Sailors or Marines as they are proscribed to human operators throughout the design and acquisition process. By capturing initial design decisions – and their underlying decision trees – and advances in technology and how they impact the role of humans in the system will be documented. Further, changes in capabilities enabled with future technologies can be accommodated and upgraded/updated recommendations could be made throughout the platform's lifecycle that adequately address the impacts to human operators and users. The evolution of systems must be considered in parallel with recommendations to the Manpower, Personnel, Training & Education lifecycle that prepares Warfighters to use these systems. Accounting for these advances will ensure that platform/system designs will continue to account for and address the needs of our Sailor and Marine end users as technologies evolve – without risking mission effectiveness.

The tools developed through this effort will assist in identifying, defining, and specifying the role of humans in using technologies in complex systems. The desired system would characterize those functions that are determined to be fundamentally human, and which must be addressed throughout the design and acquisition process, regardless of what technology solutions might be brought to bear as the system evolves. The system should provide operational descriptions of the functions, fundamental assumptions and assertions for the role of the humans interacting with these systems, along with objective (quantifiable) metrics for human performance with the system being developed. The desired capability will create a record of what humans are expected to do in the systems, and how they are addressed through the design, acquisition, and deployment process. The system would document design decisions and tradeoffs that are made, ensure that requirements are appropriately addressed, and provide structured documentation. While the desired system should be broadly applicable to a range of human-machine system teams, of particular interest are those hybrid systems that involve significant decision-making support or human-automation/autonomy interactions. Both types of systems may evolve with the introduction of artificial intelligence and/or machine learning, and significant evolution in capabilities are

## VERSION 8

expected, so use cases addressing the use of the proposed design tool(s) for these applications is highly desired. Failure to adequately consider and manage these issues during system design, development and acquisition reduce platform resiliency at the cost of a sub-optimized force and reduced mission success for the entire Naval enterprise.

**PHASE I:** Address the state of the art in system design and functional requirements tracking tools. Define how the engineering tool(s) to be developed will capture, document and track requirements related to human roles and activities in complex human-machine systems. Develop at least two use cases for how the proposed system will be used to support human-machine system design. Develop and describe a concept prototype tools / workflows / processes with storyboards, mission narratives, and functional flow diagrams (or equivalent) to demonstrate how the technology being developed will support system design. A prototype description should be developed to include appropriate standards-based approaches to defining the human role in systems to the maximum practical extent. Define operational and technical metrics that will permit the demonstration of the utility of the approach during Phase II development. Propose notional elements on how the products created using the proposed tools would be stored and disseminated across a distributed design team. Describe the functionality of the anticipated for software prototypes being developed during Phases II and III of the effort. Software will need to run on a local machine, and work well in field conditions (i.e., no internet, no external connections or cloud connections, etc.). Define the proposed transition model and a development plan for successful development through Phase III of the SBIR/STTR process. Provide a Final Phase I report that includes detailed descriptions of the development approach, and the technical challenges to be addressed in Phase II. Develop a Phase II plan that includes detailed Program Objectives and Milestones (POAM) for the duration of the project effort. Describe proposed performance criteria and metrics to be used in evaluating technical progress of the effort through Phases II and III of this SBIR project. Identify transition targets (e.g., Naval Programs of Record or potential commercial customers) who are prepared to invest in the tool during Phases II and III.

**PHASE II:** Develop, demonstrate, and refine the Phase I concept prototype(s). Validate utility in supporting the design in one or more systems. Demonstrate applicability to system design for an actual system design. The demonstration should be based upon the planned commercialization / transition strategy. The effectiveness of the tool(s) / processes for using the tool(s) shall be demonstrated by applying the utility metrics defined in Phase I, as well as any additional metrics that may be developed in Phase II. Develop and document a specific plan for Phase III transition and commercialization for the identified transition customer(s). Provide a Final Phase II report that includes a detailed description of the approach and results measured against metrics developed in Phase I.

**PHASE III DUAL USE APPLICATIONS:** Refine the prototype and make its features complete in preparation for transition and commercialization based upon the requirements of the transition customer(s). In addition to the DoD, there will be an increasing demand for human performance system design tools and techniques useful for complex systems in the commercial sector, and in federal and state agencies, for example, self-driving cars, intelligent monitoring and clinical decision support for medical devices, and geophysical surveillance for mining and agriculture. These domains, and any domain looking to inject AI into existing structures involving humans and teams of humans could benefit significantly from the application of the solutions developed in this effort.

### REFERENCES:

1. Fitts, Paul M. (ed) "Human engineering for an effective air navigation and traffic control system." National Research Council, Washington, DC, 1951. <https://psycnet.apa.org/record/1952-01751-000>.

## VERSION 8

2. Hancock, P.A. "On the future of hybrid human-machine systems." In: Wise JA, Hopkin VD, Stager P (eds) "Verification and validation of complex systems: human factors issues." Springer, Berlin, 1993, pp. 61-85. [https://link.springer.com/chapter/10.1007/978-3-662-02933-6\\_3](https://link.springer.com/chapter/10.1007/978-3-662-02933-6_3).
3. Hancock, P.A. and Chignell, M.H. "Mental workload dynamics in adaptive interface design." IEEE Trans Syst Man Cybern 18, 1988, pp. 647-658. [https://www.researchgate.net/publication/258340563\\_Mental\\_Workload\\_Dynamics\\_in\\_Adaptive\\_Interface\\_Design](https://www.researchgate.net/publication/258340563_Mental_Workload_Dynamics_in_Adaptive_Interface_Design).
4. Price, H.E. "The allocation of function in systems." Human Factors: The Journal of the Human Factors and Ergonomics Society 27, February 1, 1985, pp. 33-45. <https://journals.sagepub.com/doi/abs/10.1177/001872088502700104>.

KEYWORDS: Human; Machine; Acquisition; Life cycle; Automation; Artificial Intelligence; AI; System Design; Requirement; Technology Management; Human Factors

## VERSION 8

N221-069 TITLE: DIGITAL ENGINEERING - Digital Twins to Enable Training (DTET)

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Human Systems;Information Systems

OBJECTIVE: Develop an enterprise training solution that integrates digital twin models [Ref 1] and their related data with immersive training content capabilities and adaptive training algorithms to accelerate the acquisition of knowledge and increase learning gains with a focus on maintenance tasks.

DESCRIPTION: Current maintenance training systems lack several modern training capabilities: (1) easily created and modified immersive training content; (2) algorithms and technologies that enable adaptive and tailored training; and (3) an enterprise focus that allows for automated content creation across many domains, whether it be immersive content, tailored lesson plans, or adaptive tutoring through a curriculum. The current state of the art of digital twin technologies in development to design new systems could also be used for training and education. However, new capabilities are required to link the underlying authoritative models with immersive content creation pipelines that can leverage poor-quality source data in an automated fashion requiring minimal personnel interaction. Additionally, new training and education systems must be developed to allow for adaptive and tailored training [Ref 2] that can be applied to a variety of maintenance domains, and do not require specialized personnel to develop training content and curricula. A convergence of key enablers exists to pivot towards an immersive and tailored training approach by exploiting the availability of computer vision, advances in machine learning, and science of learning. Proposals should leverage emerging commercial technologies while addressing the technical challenges associated with supporting distributed military environments and training at an enterprise scale.

The overarching goal of this effort is to connect authoritative digital twin models, developed as part of an overarching Digital Engineering approach to streamline new platform development, with a generalized and domain-agnostic persistent training platform for automated content creation and tailored learning guidance at an enterprise scale connected to an eLearning system (such as Moodle). The immersive content creation pipeline may need to rely on a suite of technologies, such as object scanning, photogrammetry, and computer vision to create content usable in current and future classrooms [Ref 3]. These technologies should be able to be integrated with and leverage models from existing Marine Corps digital twin efforts. Respondents are expected to have existing content for which to use for the topic. Authoring, content development, and management of the tailored training system should leverage machine learning and other adaptive algorithms.

The end state of this program is a capability to leverage already-validated digital twin models as part of a broader maintenance training tool that tailors instruction to each individual student. This program should automate source material ingest and immersive content creation reducing the time to create training curricula and increase learning gains (e.g., test scores) by creating opportunities to interact with immersive content and be guided through curricula by macro- and micro-adaptive tailored training algorithms. Human Subjects testing may be needed in Phase II to assess content creation efficiency increases and training effectiveness outcomes. The anticipated skill sets necessary to support this topic are: maintenance subject matter experts, computer scientists, software engineers, instructional designers, data scientists, and human factors psychologists.

PHASE I: Develop early mockups and prototypes for software, the associated workflow and requirements for supporting an enterprise capability for source content ingest, automated immersive content creation, and adaptive learning within a Marine Corps eLearning ecosystem (e.g., Moodle). Source content could vary from static images to 3D scans of physical objects to CAD models.

## VERSION 8

Produce the following deliverables: (1) requirements for the system components including leveraging and integrating with existing Digital Twin models; (2) methods to efficiently ingest poor-quality, limited source data and automate immersive content creation; (3) learning sciences approaches for delivery of content; and (4) overview of the system and plans for Phase II, which should include key component technological milestones and plans for at least one operational test and evaluation, to include user testing.

If exercised, the Phase I Option should also include the processing and submission of all required human subjects use protocols as needed for Phase II training effectiveness evaluations. Due to the long review times involved, human subject research is strongly discouraged 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 and conduct a hands-on demonstration with Marines (coordination aided by ONR) in a designated field of maintenance (e.g., ground vehicles, radio communications, etc.). Conduct a usability assessment and perform a training effectiveness evaluation. Specifically, develop an early-stage prototype focused on no more than two task domains to support the source ingest and content creation pipeline and adaptive training technologies. Construct a survey to provide feedback from maintenance instructors and students (assistance in determining relevant population and coordinating for demonstration/field test by ONR). Collect impressions of usability, develop objective metrics of time and effort to create immersive content, and measure learning gains (including quantity and quality of acquired knowledge). Perform all appropriate engineering tests and reviews, including a critical design review to finalize the system design. Once system design has been finalized, conduct a usability test of the immersive content creation system and training effectiveness evaluation with a relevant Marine Corps population.

Produce the following deliverables: (1) a working prototype of the system that is able to interact with existing system specifications; (2) evaluation of system usability and efficiency to ingest source data and create immersive training content; and (3) a training effectiveness evaluation of system capabilities to provide demonstrable improvement to the instructor population (Human Subjects protocol needs to be approved in Phase I Option if needed for this evaluation). Institutional Review Board approval for human subjects research can take 6-12 months, and this must be taken into account if human subjects research will be part of the proposed work.

**PHASE III DUAL USE APPLICATIONS:** Support the Marine Corps in transitioning the technology for Marine Corps use. Develop the software for evaluation to determine its effectiveness in either a formal Marine Corps school setting or other training setting. As appropriate, focus on broadening capabilities and commercialization plans.

Development of affordable, scalable, non-proprietary technologies are needed in order to integrate immersive content creation and accelerated learning concepts across the DoD. The commercial sector is developing some of these technologies, but they often do not have critical issues regarding non-existent, limited, or low-quality source data, nor do they often address encryption and classification. This technology will have broad application in the commercial sector, such as in manufacturing and industrial equipment maintenance.

### REFERENCES:

1. Jones, D.; Snider, C.; Nassehi, A.; Yon, J. and Hicks, B. "Characterising the Digital Twin: A systematic literature review." CIRP Journal of Manufacturing Science and Technology, May 2020, Vol 29, pp. 36-52. <https://www.sciencedirect.com/science/article/pii/S1755581720300110>.

## VERSION 8

2. Durlach, P.J. and Ray, J. M. “Designing adaptive instructional environments: Insights from empirical evidence.” (Technical Report 1297). Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, 2011. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a552677.pdf>.
3. Feiner, Steven and Henderson, Steven. “Exploring the Benefits of Augmented Reality Documentation for Maintenance and Repair.” IEEE Transactions on Visualization and Computer Graphics, Volume 17, Issue 10 (October 2011), pp. 1355-1368. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.182.613&rep=rep1&type=pdf>.

KEYWORDS: Digital Twin; Adaptive Training; Content Creation; Maintenance; 3D Models

## VERSION 8

N221-070 TITLE: Acoustic Vector Sensors that Achieve Affordable Array Directivity

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR); Networked C3

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

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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:** Achieve substantially more affordable application of acoustic vector sensors, particularly under less extreme contexts (e.g., ocean shelf vs. deep ocean applications, fat-line vs. thin-line towed array form factors, deployment packages larger than A-sized) through concurrent application of recent acoustic vector sensor design and manufacturing advancements.

**DESCRIPTION:** Acoustic vector sensors deliver directionality by virtue of sampling the kinetic energy portion of the propagating acoustic field rather than simply the potential energy portion of that field using a hydrophone. Such directionality can be achieved via a direct measurement of acoustic particle velocity; by temporal integration of measurements of acoustic particle acceleration; by temporal differentiation of measurements of acoustic particle displacement; or by spatial differentiation of the acoustic pressure field using an adjacent pair of hydrophones. Much progress has been made in the design and employment of highly compact, low power, and low noise-floor acoustic vector sensors in applications at lower frequencies, particularly within arrays that are relatively stationary in relation to the surrounding sea water or, if moving, include a substantial decoupler. For applications under circumstances of low environmental noise and/or harsh volume constraints, high strain sensitivity materials in combination with sophisticated signal conditioning electronics have been required to deliver the requisite sensor self-noise performance. Particularly in deep ocean applications and for thin-line towed array applications, the material and manufacturing requirements for the sensor housings have been extremely challenging. Sensor and array costs and their in-situ performance have also been substantially complicated by, and in some cases compromised by, the adoption of proprietary telemetry schemes that promised low technical risk and/or avoidance of non-recurring costs. SONAR array employment at shallower ocean depths and across a larger frequency band leads to arrays with more sensor elements which simultaneously and harshly drive up array costs and telemetry bandwidths.

This SBIR topic specifically addresses cost-effective manufacturing approaches that will enable wider adoption of acoustic vector sensor technologies by making directional sensors and arrays simultaneously more effective, more reliable, and more affordable. By employing the lessons learned in design, manufacturing, and employment of acoustic vector sensors for use in the most extreme operating conditions of depth and low background environmental noise, sensible options emerge for substantially reducing the cost of manufacturing sensors good enough for more less demanding operational circumstances. A combination of these steps should reduce the total cost of a joint pressure velocity sensor by more than 50%. Specific examples might include the use of lead zirconate titanate (PZT) or textured ceramics in lieu of more expensive PMN-PT materials, or concurrent additive manufacturing of sensor housings and vector sensor accelerometer beam mechanical components, or incorporation of a government-owned (e.g., non-proprietary) signal conditioning and digital telemetry architecture to

## VERSION 8

reliably enable dramatic flexibility in array bandwidth, or some combination. Hybrid arrays that simultaneously sample the acoustic and kinetic energy field using either joint pressure-velocity sensors or co-located hydrophone/particle velocity sensors are also of interest.

PHASE I: Identify the tradeoffs between transduction materials, acoustic particle velocity sensor channel fabrication methods, telemetry alternatives, and environmental noise vs. array employment strategy to offer more cost-effective passive acoustic SONAR sensors and arrays.

The proposed approach should directly identify and address:

1. Identify and address Navy end user(s) requirements/constraints (e.g., the noise floor, size array packing volume/cost, size, weight, power requirements) that can be improved/relaxed.
2. Define clear objectives and measurable results for the proposed solution(s) – specifically how the combination of improvements will impact the end user application context.
3. Describe the cost variance and design feasibility when integrated vs a legacy capability.
4. Describe material science and manufacturing technology developments that would be required to successfully field the proposed solution(s).

Develop a Phase II plan.

PHASE II: Develop, integrate, and demonstrate a prototype acoustic vector sensor determined to be the most feasible solution during the Phase I period. The demonstration should focus on:

1. Evaluate the proposed solution vs performance requirements and cost and reliability objectives defined in Phase I.
2. Describe in detail how the resulting sensor design and production innovations can be adopted widely.
3. Identify a clear transition path by which a solution appropriate to a specific transition context can be advanced in collaboration with transition stakeholders.
4. Incorporate specific feedback from transition customer(s) regarding how the proposed solution can be integrated, supported, sustained, and relied upon to reduce acoustic vector sensors costs and to support the unique priorities of other applications/customers.

PHASE III DUAL USE APPLICATIONS: Expand mission capability vs. affordability options to include a broad range of government and civilian users and applications. Coordinate with the government for additional research and development, or direct procurement of products and/or services developed in coordination with the Navy.

### REFERENCES:

1. Butler, Stephen. “Properties of Transducers: Underwater Sound Sources and Receivers.” Naval Undersea Warfare Center Division Newport, Rhode Island (NUWC) Technical Document 12,289, 19 Dec 2018. <https://apps.dtic.mil/sti/pdfs/AD1068326.pdf>.
2. Caldwell, S.A. and Faella, J.A. “Open Architecture Telemetry Specification for Single Three Axis Vector Sensor Nodes in Thin Line Towed Arrays.” Naval Undersea Warfare Center, Division Newport, Rhode Island (NUWC-NPT) Technical Document 12,345, 11 July 2019.
3. Faella, J.A. “Interface Control Document for Sensor Nodes using Open Architecture Telemetry (OAT) in Towed Arrays.” Naval Undersea Warfare Center, Division Newport, Rhode Island (NUWC-NPT) Technical Document 12,341, 20 August 2019.

KEYWORDS: acoustic vector sensor; acoustic particle velocity; PMN-PT single crystal material; lead zirconate titanate; PZT ceramic material; Open Architecture Telemetry; textured ceramics



## VERSION 8

N221-071 TITLE: Forensic Memory for Self-Cued, Data-Thinning Receivers

OUSD (R&E) MODERNIZATION PRIORITY: 5G;Microelectronics;Networked C3

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

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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:** Demonstrate a digitally-based, forensic First-In, First-Out (FIFO) memory technology. Then, at a threshold level of performance, develop methods to locate within the exiting flowing data the specific subset corresponding to cued time/frequency segments and deliver them into a back-end data fusion processor. At the objective level of performance, demonstrate successful sub-nanosecond re-aggregation of common time of arrival events from multiple disjoint frequency subchannels. Ensure memory concepts are compatible with data rates scaling to multi-bit, 40 GSamples per second or more and provide time offsets of 100 microseconds or more per modular copy. Consider desirable low power operation and low acquisition cost.

**DESCRIPTION:** The increasing military use of highly adaptive transmit signals mean that U.S. electronic support receivers need to respond to unpredicted single pulses. Hence they need to include the ability to self-cue on signals within their input bandwidth that just appeared in the spectrum and match the current criteria of signals of interest. Unfortunately, by the time the new signal is detected and categorized as of interest, its occurrence is often over. Hence unless the entire spectrum has been recorded, there is then no possibility to study that first occurrence in greater detail, especially if the data was consumed in the event detection process. In particular, there is no way to look just before the pulse's onset to see whether there is a characteristic precursor signal. What is needed is a forensic memory, a way to look back in time and access the entire signal after it is declared of interest. To be practical, this memory ought not to require massive RAM memories, cost, or power consumption to operate and should produce a long enough delay to allow digital processors working in parallel on multiple, identical quality copies of the entire spectrum data sufficient time to provide cueing information for all the currently prioritized events of interest happening in the given time window.

Today such memories do exist where a power divider sends an analog copy of the signal into passive optical fiber, while the rest of the received energy feeds a receiver that detects the signals of interest (SOI). This architecture can work but requires substantial distortion--inducing amplification to achieve long enough delays and often an entire digitization front end per SOI output. For full spectrum, many simultaneous signal systems, the cost and complexity/volume of the resulting redundant hardware and control networks becomes prohibitive.

Future ES systems need to surveil over 20 GHz of instantaneous bandwidth and respond to a variable but potentially large number of simultaneous signals in all frequency channels monitored, without having the rigidity of designating which frequency channel a given processor addresses. The Analog to Digital Converters required increasingly exist. What is missing is a way to capture and hold temporarily the digital representation of the entire spectrum and then in real time fan out perfect copies to a scalable set of following digital processors that have been cued as to the time, as well as frequency, of the individual SOI

## VERSION 8

they are to process. The ability to aggregate information derived from disjointed frequency channels is also required. A permanently-record-everything approach allows deep inspection of what happened, but normally only after the immediate operational value of the information has expired. It also requires prodigious volumes of memory that consumes energy and volume and manpower to keep changing storage devices. Real-time systems must have a way to reduce the volume of data being extensively processed to what processing the system can accomplish in real time. Therein copies of the same digital data as used for event detection/cue preparation need to be sent to the data thinning circuits. Memory delays sufficiently long for the cues to be prepared and prioritized for further attention are required. Ideally the temporary digital data storage mechanism should not depend on the digital data sample rate. Here the first demonstration ought to consider use of the COTS 100 GbE fiber data links commonly used in server farms. Other solutions suitable for > 20 GSps multi-bit analog to digital converters (ADC) will be considered if the proposals persuasively argue their applicability to real time processing of dense signal environments.

Proposals must define a detailed path to an experimental demonstration of the memory module during the Phase I base period and a more notional plan for demonstrating the entire self-cued data thinning system before the end of the Phase II base period. These plans need to discuss how any components/functionality not existing today would be produced and with what technical risks.

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

**PHASE I:** Demonstrate the feasibility of a way of providing a properly synchronized FIFO copy of 3 or more bit wide digital words at a flowing data rate above 20 GSps with time delays above 100 microseconds and a bit error rate below 10<sup>-12</sup>. Prepare a preliminary Phase II plan that discusses how to scale to wider words, higher data rate, and longer delays, plus comment on details like the impact of data packetization on the system performance. The Phase I option work, if exercised, should complete the production of the prototype memory module suitable for multi-bit 40 GSps ADCs and ideally demonstrate scaling to longer delays with no drop in BER, the bit error rate.

**PHASE II:** Develop and demonstrate a modular, adaptive, high bandwidth data thinning system. Functionalities that shall be demonstrated include: 1) proper recovery of a truncated data set containing the data that produced the self-cueing alert for a single < 10% duty cycle signal; 2) two differently processed signals from the same frequency sub-band within the same original data stream arriving into a data fusion processor with the proper relative timing; and 3) two differently processed signals from different frequency sub-bands within the same original data stream arriving into a data fusion processor with the proper relative timing. Progress on monitoring and controlling the absolute delivery- time delay and inserting the delayed data into the further back processors will be expected. Preference will be given to proposed efforts with little development work on the cue producing subsystem. The Phase II option effort, if exercised, shall incorporate the new delay module in some existing, probably classified signals analysis system and demonstrate the improved functionality. A proof that the improved system's operation is independent of the signal waveform is expected to be included.

## VERSION 8

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

PHASE III DUAL USE APPLICATIONS: Full integration of the time delay unit into a working, classified ES system is predicted and tests of its performance advantages will follow. If the suggested server farm data links can be adapted for this use, the topic will be a dual use application, but the technology advancement driver will be dominated by the commercial side of the equation.

### REFERENCES:

1. MKS Newport. (n.d.). "Compact Time Delay Coils." <https://www.newport.com/f/compact-time-delay-coil>.
2. Gupta, D.; Sarwana, S.; Kirichenko, D.; Dotsenko, V.; Lehmann, A. E.; Filippov, T. V.; Wong, W.-T.; Chang, S.-W.; Ravindran, P.; and Bardin, J. "Digital output data links from superconductor integrated circuits." IEEE Transactions on Applied Superconductivity, 29(5), 2019, pp. 1-8. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8686133>.
3. Stieber, S.; Dorsch, R.; and Haubelt, C. "Accurate Sample Time Reconstruction of Inertial FIFO Data." Sensors (Basel, Switzerland), 17(12), 2894, 2017. <https://doi.org/10.3390/s17122894>.
4. Coffey, J. "Latency in optical fiber systems." COMMSCOPE, 2017. <https://www.commscope.com/globalassets/digizuite/2799-latency-in-optical-fiber-systems-wp-111432-en.pdf>.

KEYWORDS: First-in-first-out memory; FIFO; adaptive signals; Electro-magnetic support systems; time delay; digital data transmission; channel/time domain synchronization

## VERSION 8

N221-072 TITLE: Low-Cost Deployable Structures for Sonobuoy Arrays

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR);Microelectronics

TECHNOLOGY AREA(S): Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 affordable and reliable high packing ratio deployable structures for advanced sonobuoy arrays to enable future U. S. Naval anti-submarine warfare operations.

**DESCRIPTION:** The Department of the Navy (DON) seeks to develop and demonstrate reliable deployable structures for highly capable volumetric acoustic arrays from compact air-deployed canisters. These arrays require stability once deployed with the sensor elements having predictable and repeatable spacing to allow optimal system array performance. The deployable structures should be acoustically quiet and transparent and/or not interfere with any acoustic nodes that may be placed on the structure. Sonobuoy deployable arrays are deployed from patrol aircraft or helicopters and need to meet all the requirements of production sonobuoys. The deployable structures need to be able to reliably deploy even after resting up to five years on the shelf. The deployable mechanisms need to fit within the confines of the A-size sonobuoy (18" x 5") and expand to a cylindrical array up to 6,100x the original volume all while holding ~100 sensor nodes. The lifetime of these systems once deployed should be no more than a day and the overall cost of the deployment system should be less than \$500.

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

PHASE I: Develop a conceptual design for the proposed component(s) and its integration into a chosen deployable array. Phase I awardees will be granted access to specifications of production sonobuoys. Conduct a conceptual design review of the analysis and results of Phase I work. Develop a Phase II plan.

PHASE II: Develop and test a prototype for the key components of the proposed approach. Complete preliminary performance testing in a surrogate environment such as a large tank or lake test facility. Report the results of testing and analyze the expected performance for the reference mission.

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

## VERSION 8

PHASE III DUAL USE APPLICATIONS: Integrate the technology using the prototype fabricated in Phase II. Conduct a demonstration to examine mission performance under nominal operating conditions. Based on the results, analyze performance in a variety of suboptimal environments and conditions.

### REFERENCES:

1. "All Products from Sonobuoy Tech Systems." <https://www.sonobuoytechsystems.com/products/>.
2. Filipov, Evgueni T. et al. "Origami tubes assembled into stiff, yet reconfigurable structures and metamaterials." PNAS, October 6, 2015 112 (40), pp. 12321-12326. <https://www.pnas.org/content/112/40/12321>.
3. Cavallaro, P.; Hart, C. and Sadegh, A. "Mechanics of Air-Inflated Drop-Stitch Fabric Panels Subject to Bending Loads." NUWC-NPT Technical Report #12,141, 15 August 2013. [https://www.researchgate.net/publication/267596423\\_Mechanics\\_of\\_Air-Inflated\\_Drop-Stitch\\_Fabric\\_Panels\\_Subject\\_to\\_Bending\\_Loads](https://www.researchgate.net/publication/267596423_Mechanics_of_Air-Inflated_Drop-Stitch_Fabric_Panels_Subject_to_Bending_Loads).
4. Smith, Hillary. "Deployable Composite Booms (DCB)." NASA, Aug 27, 2020. [https://www.nasa.gov/directorates/spacetech/game\\_changing\\_development/projects/dcb](https://www.nasa.gov/directorates/spacetech/game_changing_development/projects/dcb).
5. Holler, Roger; Horbach, Arthur and McEachern, James. "The Ears of Air ASW." Navmar Applied Sciences Corp., Warminster PA, 2008. <https://www.worldcat.org/title/ears-of-air-asw-a-history-of-us-navy-sonobuoys/oclc/720627294>.

KEYWORDS: Undersea sensor; deployable array; sonobuoy

## VERSION 8

N221-073 TITLE: Radio Frequency Spectrum Patterns of Life

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML);General Warfighting Requirements (GWR);Networked C3

TECHNOLOGY AREA(S): Electronics;Ground / Sea Vehicles;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 the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop an automated system that characterizes the Radio Frequency (RF) emitter behaviors and patterns of life for a geographic area with no to minimal operator intervention.

DESCRIPTION: The RF spectrum is a congested medium shared by a wide range of private, commercial, civil, and military users to communicate, navigate, and characterize the environment using increasingly diverse signal waveforms and shared-access methods. Spectrum use varies as a function of time, space, and frequency, resulting in a highly dynamic environment that challenges traditional methods of spectrum monitoring and evaluation. This lack of understanding limits the use of opportunistic spectrum applications (e.g., cognitive radio, dynamic spectrum access) and makes it difficult to detect anomalous spectrum use.

Despite the dynamic nature of spectrum use, most of the activity is routine, and therefore potentially predictable. In much the same way that human cognition works, learned models of expected or predictable features and feature dynamics of the environment can be used to focus attention primarily on new or unusual features. Such an approach is necessary when constrained resources are required to make sense of complex situations. By reducing the amount of information that must be processed at any given time, the limited available resources can be allocated more efficiently to characterize the most important aspects of the environment, not wasted by repeatedly evaluating the same features and behaviors.

To support this objective, this SBIR topic will explore algorithms that detect, characterize, and learn “normal” spectrum activity and behaviors. Learned models should be able to represent signal types and their temporal and spatial qualities sufficiently to predict when and where typical activity will occur. An important aspect of this research will be to demonstrate ways that the learned model can be used to focus attention on novel signals in the spectrum, as well as unusual spectral patterns of activity. Note that methods of interest must be able to generalize over a wide range of signal types, including those used by communications devices and radars. Approaches that operate only on limited or specific signal types are not of interest.

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

## VERSION 8

requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Conduct a study to evaluate the technical feasibility of learning RF spectrum patterns of life to automatically bring to the operators attention novel and unusual activities in the RF environment. Given a simple radio receiver (e.g., single channel,  $\leq 500$  MHz instantaneous bandwidth,  $\sim 18+$  GHz tuning range), develop an approach to learn spectrum patterns for a day in the life of a moderately congested RF environment (e.g., an airport, a littoral maritime environment). Demonstrate for a simulated environment that the learned model can discriminate between new signals and those normally present in the environment when a new signal shares several attributes (waveform, frequency, timing, etc.) with those signals typically present in the environment. For example, the system should be able to detect when an arbitrary but common communications signal appears at an unusual frequency or time of day, or when a radar changes its' waveform or pulse repetition rate to something not previously observed. Develop a Phase II plan.

PHASE II: Given a set of 3-4 simple receivers geographically distributed to span an 100 SQ mile area of interest, develop an approach to learn spectrum patterns for a day in the life of a moderately congested RF environment. Demonstrate in a lab environment that the learned model can detect unusual signals and spectral activities that vary over space, time, frequency, and/or signal type. Build and deliver a prototype system that can monitor the RF spectrum, collect sufficient examples to train the learned model, and then operate in near-real-time to identify spectrum anomalies.

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 an improved spectrum patterns of life modeling system integrated onto a fielded RF sensor(s). The system will show that it achieves the objective capability described above. Deliver the prototype to be independently evaluated by the Government to determine if the technology has the potential to meet the Navy's performance goals for patterns of life modeling.

Develop an automatic capability for RF spectrum monitoring and analysis by commercial ventures who enforce Spectrum utilization for the Federal Communications Commission (FCC) and Homeland security. This capability can also be used by cell tower infrastructure companies to understand the RF environment they are placing new or existing cellular infrastructure in.

### REFERENCES:

1. Liu, Song; Greenstein, Larry J.; Trappe, Wade and Chen, Yingying. "Detecting anomalous spectrum usage in dynamic spectrum access networks." Ad Hoc Networks 10, no. 5, 2012, pp. 831-844.  
<https://personal.stevens.edu/~ychen6/papers/Detecting%20Anomalous%20Spectrum%20Usage%20in%20Dynamic%20Spectrum%20Access%20Networks.pdf>.
2. Rajendran, Sreeraj; Meert, Wannes; Lenders, Vincent and Pollin, Sofie. "SAIFE: Unsupervised Wireless Spectrum Anomaly Detection with Interpretable Features." 2018 IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN), IEEE, 2018, pp. 1-9.  
<https://arxiv.org/pdf/1807.08316.pdf>.
3. Zhijing, Li;, Xiao, Zhujun; Wang, Bolun; Zhao, Ben Y. and Zheng, Haitao. "Scaling Deep Learning Models for Spectrum Anomaly Detection." Proceedings of the Twentieth ACM International Symposium on Mobile Ad Hoc Networking and Computing, 2019, pp. 291-300.  
<https://dl.acm.org/doi/pdf/10.1145/3323679.3326527>.
4. Selim, Ahmed; Paisana, Francisco; Arokkiam, Jerome A.; Zhang, Yi; Doyle, Linda and DaSilva, Luiz A. "Spectrum Monitoring for Radar Bands using Deep Convolutional Neural Networks."

## **VERSION 8**

GLOBECOM 2017-2017 IEEE Global Communications Conference, 2017, pp. 1-6.  
<https://arxiv.org/pdf/1705.00462>.

KEYWORDS: Electronic Surveillance; Radio Frequency; RF; Spectrum Monitoring; Patterns of Life; Emission Classification; signals intelligence; SIGINT



## VERSION 8

N221-074 TITLE: Turbine Engine Efficiency improvements by Additive Manufacturing

OUSD (R&E) MODERNIZATION PRIORITY: Artificial Intelligence (AI)/Machine Learning (ML);General Warfighting Requirements (GWR)

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

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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: Link heat transfer and solidification modeling, material databases, innovative cooling design concepts, and Additive Manufacturing (AM) process variables that will enable repair and enhanced efficiency improvements for gas turbine blades and other potential high temperature engine components.

DESCRIPTION: Improving engine performance requires creating new materials and improving design and manufacturing. AM is capable of producing details of complex shapes that cannot be produced by traditional methods. AM could produce nickel-based turbine blades with complex geometries with optimized internal cooling pathways and lattice-structure interiors.

Microstructural control can enable tailored properties. Modeling and simulation tools that analyze thermal flow and solidification, coupled with alloy property databases within a machine learning framework, can link varying AM process variables to arrive at new complex blade designs with optimized, integrated cooling networks and lattice blade structures rather than solid blades to reduce blade weight and improve engine efficiency by increasing operational engine temperatures. Fabricating blades in this manner would avoid current processing steps. With AM processing of these complex architectures, the effects of internal surface roughness will also need to be evaluated.

The AM process should present unique designs not possible with more conventional fabrication processes. The use of AM could lead to more innovative designs capable of more efficiently removing heat for both Navy and commercial applications. The outcome of this technology development effort will be a commercial suite of informatics-derived tools that can be able to reliably analyze and discriminate various sources of materials databases to optimize the capability for developing and new design and fabricating turbines blades with more effective use of the cooling air available to the engine.

PHASE I: Explore the literature to determine the initial AM parameters for a nickel-based superalloy such as Alloy 738 or 718. The focus of Phase I will be to fabricate a generic artifact with a simple network of internal cooling holes, overhangs, and thin/thick sections. The performer can suggest the artifact for evaluation. Suggested size would be an isosceles triangle cross-section about 3-inches (7.5cm) long. The unequal side should be 1-inch (2.5-cm) wide. The company should select an AM process capable of sufficient control and resolution to enable a good understanding of the heat transfer, solidification variables, and other material/process factors which cause defects. Develop conceptual models/algorithms that link alloy chemistry/heat transfer/solidification to the AM process shows geometric and material control while minimizing defects. Consideration will be given to the size of the internal holes and cooling network generated. Analysis of the defects is suggested to be done by non-destructive processes such as

## VERSION 8

optical tomography, in-situ thermographic analysis, ultrasonic monitoring or x-ray tomography. ICME should link to AM process parameters with defect frequency and distribution in the component design, employ and prove feasibility of an approach for a metal AM method. Develop a Phase II plan.

PHASE II: Focus on increasing complexity of the linked AM process and on fatigue critical properties and temperature ranges of interest. In addition to evaluation of microstructure, Phase II should focus on fatigue critical properties at temperature ranges of interest. The AM process should be assessed to fabricate an internal surface roughness that maximizes cooling effectiveness. Further evaluation of effects of defects and control of defects should provide a more in-depth link to ICME-based tools. Residual stress should also be considered within modeling and fabrication tools to reduce residual stresses during fabrication and prevent cracking. The company should work with a turbine engine Original Equipment Manufacturer (OEM). The OEM should provide a range of conditions (cooling channel size, pressure drop tolerance, cooling efficiency).

PHASE III DUAL USE APPLICATIONS: Commercialize the alloys for use in DoD and commercial markets. Engage with the Government and/or public, commercial, company, or professional technical societies that retain materials databases. Interface with a software company that promotes and delivers materials computational programs to explore and develop an integration pathway for the database discriminating program with their software. Transition the material production methodology to a suitable industrial material producer. Transition the ICME code to the commercial entity for potential incorporation of a more comprehensive ICME code.

### REFERENCES:

1. Carter, L.N.; Attallah, M.M. and Reed, R.C. "Laser Powder Bed Fabrication of Nickel-Base Superalloys: Influence of Parameters; Characterisation, Quantification and Mitigation of Cracking." Superalloys2012, 12th International Symposium on Superalloys, The Minerals, Metals, and Materials Society, pp. 577-586.  
[https://www.tms.org/superalloys/10.7449/2012/Superalloys\\_2012\\_577\\_586.pdf](https://www.tms.org/superalloys/10.7449/2012/Superalloys_2012_577_586.pdf).
2. Sames, W.J.; List, F.A.; Pannala, S.; Dehoff, R.R. and Babu, S.S. "The metallurgy and processing science of metal additive manufacturing." International Materials Reviews, Vol. 61, Issue 5, 2016, pp.315-360.  
<https://www.tandfonline.com/doi/abs/10.1080/09506608.2015.1116649?journalCode=yimr20>.
3. Parimi, L.L.; Ravi, G.; Clark, D. and Attallah, M.M. "Microstructural and texture development in direct laser fabricated IN718." Materials Characterization Vol. 89, March 2014, pp, 102-111.  
<https://www.sciencedirect.com/science/article/pii/S1044580313003835>.
4. Lippold, J. "Welding Metallurgy and Weldability." John Wiley & Sons, Inc., Hoboken, New Jersey, 2015. <https://onlinelibrary.wiley.com/doi/book/10.1002/9781118960332>.

KEYWORDS: Additive manufacturing; AM; turbine components; materials databases; machine learning; modeling; solidification; design; heat transfer; AM defects

## VERSION 8

N221-075 TITLE: Enhanced Lethality Warhead

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR);Hypersonics

TECHNOLOGY AREA(S): Materials / Processes;Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with 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 new warhead configurations that leverage new and existing energetic and reactive materials in addition to novel design and manufacturing tools to significant increase warhead damage on target to achieve (1) decreased warhead size and weight while maintaining the lethality of today's fielded weapons (e.g., Harpoon, LRASM for anti-ship), and (2) increased warhead lethality in the same form-factor to allow previously undersized weapons to engage a broader range of difficult target sets.

**DESCRIPTION:** Conventional kinetic weapons generally rely on some combination of high explosive formulation fill and inert metal fragments to damage targets. Mechanisms include detonation/shock wave, post-detonation-combustion/blast, and fragment perforation. Legacy warhead designs are often decades old and do not incorporate state of the art ingredients and design concepts. More importantly, these weapons are proving inadequate for emerging and even current threats, as they were originally developed for different historic target sets. Where more complex explosive responses are desired for special target applications and lethality enhancements, few material solutions have been available short of combinations of legacy warhead design features: complex fuzing, shape-charge jets, enhanced-blast fuel addition, etc.

More recently, advances in warhead material solutions and manufacturing/prototyping methods are emerging and have untapped potential to facilitate the development of modernized, enhanced lethality warheads with greater target damage potential at equal and reduced form-factors. For example, high density reactive materials (HDRM) are being explored for fragmenting warhead applications, providing additional incendiary and overpressure effects beyond conventional steel fragments. This will result in enhanced lethality and a reduction in the number of fired munitions to achieve confirmed kill on specific target sets, while maintaining the same warhead form-factor. 3D printed explosives and fragment architectures are also of recent interest for fragmentation size/shape control and directional damage effects on targets rather than conventional 360-degree blast and fragment dispersal.

While examples like reactive materials and 3D printing have been under development for decades, there remain numerous challenges and great potential for further warhead technology development and maturation. For instance, recent efforts, including those pertaining to HDRM fragmenting warheads, demonstrate the need for less complex, lower cost reactive material prototyping and manufacturing. In addition, accurate models are needed to facilitate adequate target damage credit for new warhead effects in main-stream lethality tools (AJEM, ASAP, etc.). Numerous other technical challenges and examples of desired warhead technologies include but are not limited to: explosive formulation 3D printing of complex shapes vs. poured/casted billets, bi/tri-metallic 3D printing of warhead relevant materials (titanium, tungsten, steel, zirconium, aluminum, etc.), incorporation of highly survivable (temperature, vibration) warhead materials (structural, energetic, or both), exploration of other tertiary lethal

## VERSION 8

performance effects (e.g., enthalpic chemical reactions), combinations of the above to provide directional and selectable effects on target, and overall, a more complete fundamental understanding of how to take advantage of the specific location of metal and other reactive components within a warhead to control mixing/combustion/blast process fluid dynamics. Considering recent progress in warhead relevant ingredients, new processing, prototyping and manufacturing methods, material models and predictive design tools in tangential technology areas, it is anticipated that the “toolbox” of warhead material combinations and configurations can be greatly expanded and demonstrated to assure future Naval weapon overmatch.

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

PHASE I: Develop and design, on paper, several feasible candidate warhead concepts using any combination of previously described or other novel technologies. Describe candidate prototype configurations and architectures in terms of: (1) expected lethality enhancements, (2) suitability for weapon speed regime (subsonic, supersonic, and hypersonic), (3) suggested warhead mass/volume/form factor, (4) example platform/weapon, and (5) example target sets.

Identify anticipated materials, manufacturing methods, design tools, and other relevant technologies that would enable the candidate warhead designs. Identify Technical and Manufacturing Readiness Levels (TRL/MRL) and cost of identified materials, methods, and other tools.

Complete initial modeling/simulation to provide some level of lethality assessment for candidate warhead concepts. At this stage, this modelling needs to be able to show that the new design has the potential to meet increased lethality goals. While this task may require Navy/DoD laboratory collaboration, truly high fidelity modelling is not the goal; the focus of the project is novel design/material use/et al.

Down-select to the most promising warhead designs and create technology and critical experiment demonstration plans and roadmaps.

Develop a Phase II plan.

PHASE II: Create preliminary designs for Phase I down-selected prototypes and execute material development and testing, demonstrating affordable and scalable manufacturing.

Execute critical experiments to demonstrate warhead concept(s) feasibility for lethality enhancements in laboratory/field test environment as appropriate. Sub-scale and sub-component test iterations are expected at this stage for concept refinement.

Complete detailed modeling and simulation, using higher fidelity tools as appropriate, to assess lethality for each prototype against selected target sets.

Pursue partnerships and work with appropriate DoD and/or DoD contractor points of contact (POCs) to down-select to the most promising prototypes. Create Phase III design, build, and demonstration plan(s).

## VERSION 8

It is likely that work and information exchanges during Phase II will become classified (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Complete detailed prototype design of down-selected concept(s), build prototype(s) and complete laboratory/field environment testing.

Leverage DoD/DoD Contractor POCs for transition of manufacturing capabilities as appropriate and transition into programs of record (POR) and/or other advanced demonstration programs.

### REFERENCES:

1. Cooper, P.W. and Kurowski, S.R. "Introduction to the Technology of Explosives." Wiley-VCH, New York, 1996.
2. U.S. Army Material Command. "Engineering Design Handbook: Warheads – Introduction." CreateSpace Independent Publishing Platform, March 5, 2018.  
<https://www.amazon.com/Engineering-Design-Handbook-Warheads-Introduction/dp/1986181871>.
3. Carleone, J. "Tactical Missile Warheads." Progress in Astronautics and Aeronautics, AIAA, Reston, 1993.
4. Lloyd, R. "Conventional Warhead Systems Physics and Engineering Design." Progress in Astronautics & Aeronautics. AIAA, Reston, 1993.

KEYWORDS: Weapons; Warheads; Energetic Materials; Explosives; Reactive Materials; Lethality

## VERSION 8

N221-076 TITLE: Lightweight, Compact, and Cost-effective Gaseous Hydrogen Storage System

OUSD (R&E) MODERNIZATION PRIORITY: Autonomy; General Warfighting Requirements (GWR)

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

OBJECTIVE: Develop a lightweight, compact, and cost-effective gaseous hydrogen storage system for Naval Aviation applications.

DESCRIPTION: Hydrogen fuel cells are gaining traction for propulsion and power requirements of small unmanned air systems (UAS) [Refs 1-4]. Compressed hydrogen is the most attractive form for hydrogen storage; however, flight-worthy storage vessels can be heavy, bulky, and expensive [Refs 5,6]. This can lead to sub-optimal vehicle designs by placing excessive volume constraints on UAS manufacturers for hydrogen fuel storage and added costs to users.

This SBIR topic seeks innovative concepts for low cost, high performance gaseous hydrogen (GH<sub>2</sub>) storage tanks for use in UAS. The Navy and USMC are interested in conformal and traditional storage vessels. Concepts include, but are not limited to, (1) conformal storage tanks that fit into either vehicle wings or non-traditional air vehicle form factors [Ref 7], and (2) novel coatings and materials for Type IV tanks that reduce cost without sacrificing robustness. The proposed concepts will be evaluated on their hydrogen storage performance metrics. Metrics include stored hydrogen weight per storage system (including regulator) weight, total volume of storage system, refill rate, manufacturability, and cost (dollar per system-weight of hydrogen stored). An understanding of how hydrogen storage systems can act as structural elements of the UAS is desired.

The GH<sub>2</sub> storage tanks must be compatible with Groups I-III UAS including environmental, shock, and vibration requirements of MIL-STD-810H [Ref 8]. Solutions must demonstrate the safe operation of the vessels including fill, storage, and use of hydrogen [Ref 9]. Solutions must also show refill capabilities using standard interfaces and a cycle lifetime of over 1,000 cycles.

The storage system designs should focus on:

- 200 g minimum GH<sub>2</sub> stored, can perform trade study on size and weight impacts for >200 g
- Operating pressures from 350 to 700 bar
- Storage minimum of 7 wt% GH<sub>2</sub> per storage system
- UAS integration

PHASE I: Develop a conceptual design of a gaseous hydrogen (GH<sub>2</sub>) storage system for a minimum of two hundred grams (200 g) of compressed GH<sub>2</sub>. Identify and model the trade space for key storage system characteristics. Show feasibility for the integration into the Unmanned Aerial System (UAS) through the use of conceptual drawings or modeling and simulation. Perform initial analyses on GH<sub>2</sub> consumption rates based on government-selected fuel cells and UAS propulsive and power requirements to meet UAS endurance targets. Produce a final Phase I report that includes plans for a storage system that stores 200 g GH<sub>2</sub> and does so at operating pressures from 350-700 bar with a storage minimum of 7 wt.% GH<sub>2</sub> per storage system. Develop a Phase II plan.

PHASE II: Build a prototype GH<sub>2</sub> system that is lightweight, compact (>20g H<sub>2</sub>/L), safe, and cost-effective.

PHASE III DUAL USE APPLICATIONS: Incorporate the system into existing and/or future UASs of defined form factors. Target development of larger GH<sub>2</sub> storage systems. Work with the DoD and partners to mature and manufacture products to produce systems that are lightweight, compact, and cost-

## VERSION 8

effective and can be used on UASs that require longer duration flight and highly adaptable form factors. The platforms of potential applicability do not rely solely on military UAVs, but also in UAVs for commercial/private use and the use of city and local governments and law enforcement. Smart agriculture, critical infrastructure inspections, and perimeter security are all likely dual-use applications.

### REFERENCES:

1. Blain, Loz. "ZeroAvia's Val Miftakhov makes a compelling case for hydrogen aviation." New Atlas, June 15, 2020. <https://newatlas.com/aircraft/interview-zeroavia-val-miftakhov-hydrogen-aviation/>.
2. Harrington. "Boost Commercial UAV Flight Times With Hydrogen Fuel Cell Technology." sUAS News, 26 April 2019. <https://www.suasnews.com/2019/04/boost-commercial-uav-flight-times-with-hydrogen-fuel-cell-technology/>.
3. Arat, H.T. and Sürer, M.G. "Experimental investigation of fuel cell usage on an air Vehicle's hybrid propulsion system." International Journal of Hydrogen Energy, Volume 45, Issue 49, October 2, 2020. <https://www.sciencedirect.com/science/article/abs/pii/S0360319919337784#!>.
4. Swider-Lyons, Karen et al. "Hydrogen Fuel Cells for Small Unmanned Air Vehicles." ECS Transactions, Vol. 64, Issue 3, 2014. 10.1149/06403.0963ecst
5. Hydrogen and Fuel Cell Technologies Office. (n.d.). "Hydrogen storage." Department of Energy. <https://www.energy.gov/eere/fuelcells/hydrogen-storage>.
6. Rivard, Etienne; Trudeau, Michel and Zaghbi, Karim. "Hydrogen Storage for Mobility: A Review. Materials." Materials, Vol. 12, Issue 12, 1973. 10.3390/ma12121973
7. Scheffel, Phillip. 'TUBESTRUCT integral high-pressure tube tank The basic idea is a single-tube structure of a wing, where the tubes are loaded under high internal pressure as well as able to absorb thrust and torsion loads from stresses in the flight. The tubes can absorb hydrogen, methane or other volatile gases.' Patent DE102015008178A1, February 2, 2017. <https://patents.google.com/patent/DE102015008178A1/en>.
8. US Army Test and Evaluation Command. "MIL-STD-810H, Department of Defense test method standard: environmental engineering considerations and laboratory tests." Department of Defense, January 31, 2019. [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H\\_55998/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/).
9. Safety of Mobile Hydrogen and Fuel Cell Technology Applications: An Investigation by the Hydrogen Safety Panel, PNNL-29341, October 2019. [https://h2tools.org/sites/default/files/Safety\\_of\\_Mobile\\_Hydrogen\\_and\\_Fuel\\_Cell\\_Technology\\_Applications-Oct\\_2019.pdf](https://h2tools.org/sites/default/files/Safety_of_Mobile_Hydrogen_and_Fuel_Cell_Technology_Applications-Oct_2019.pdf).

KEYWORDS: Hydrogen; Unmanned Aerial Systems; UAS; Conformal; Fuel Cells; Lightweight; Cost-effective; Sustainability

## VERSION 8

N221-077 TITLE: DIGITAL ENGINEERING - Semantically-Driven Data Integration Software Solutions

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR)

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 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 solution to facilitate the integration of data across disparate electronic sources of technical information in accordance with a pre-defined ontology that semantically informs that integration through prescribed concepts and relationships. Solutions must directly address challenges associated with cross-tool/cross-vendor inoperability.

**DESCRIPTION:** As Strategic Systems Programs (SSP) transitions from traditional, document-based engineering processes to a digital engineering approach, more and more software tools and databases are being used to create, modify, and analyze massive amounts of data during all phases of a given system's lifecycle. Though many domain-specific modeling tools and capabilities are quite mature and meet the needs of the day, the ability to associate/link technical data across domains in a semantically consistent manner is severely lacking. While commercial digital threading solutions exist, none of them are either semantically-driven in nature or have been validated in digital engineering environments representative of SSP's. The absence of tools for rigorous integration poses a significant risk for large acquisition programs as inconsistencies in data across domain tool and database boundaries could lead to faulty analysis results and poor decisions during key stages during the engineering design process.

To support the development of its model-based and digital engineering environments, SSP needs novel software solutions to create a dynamic "data fabric" across disparate electronic sources of technical information in accordance with a pre-defined ontology. These semantically-driven "data integrators" should facilitate, either automatically or semi-automatically, the integration of data through tool-specific means that enforce adherence to the ontology and provide the following functionality:

- Retrieve data from the various data sources (e.g., model files, applications, and databases) collectively considered an authoritative source of truth (ASOT),
- Associate/link data across various data sources and convert one tool-specific language convention to another,
- Infer duplicate entities across and merge into single representations as needed,
- Push "round trip" changes between data sources through the integrator subject to certain synchronization triggers,
- Obfuscate data based on user/organization roles and access restrictions when required, and,
- Provide a means to traverse data across sources to understand and analyze the entire dataset.

Candidate data integration solutions must be compatible with the Web Ontology Language (OWL) files generated with the Protégé ontology and knowledge management system [Ref 3]. Minimum desired target data sources include IBM Rational DOORS for system requirements, No Magic Cameo Systems Modeler (CSM) for use cases and architecture (i.e., model-based system engineering), and PTC Windchill for



## VERSION 8

various other artifacts including mechanical (mCAD) and electrical (eCAD) computer aided design models.

PHASE I: Develop an approach to semantically integrate targeted data sources based on SSP's required capabilities and preliminary requirements. Phase I efforts shall articulate the functional design, algorithms, and framework required for interfacing with CSM, DOORS, and Windchill. Additionally, Phase I deliverables shall include detailed information regarding the software architecture and identification of a robust set of test cases that will be used to verify functionality. Licenses for all commercial software to be employed are required. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Develop a semantically-driven data integrator prototype that incorporates data from CSM, DOORS, and Windchill and demonstrate functionality with a sample data set. Phase II shall include testing based on test cases identified in Phase I (updated during prototype development, as needed). Lastly, the prototype shall demonstrate functionality to representative members of the SSP user community, implement prototype updates per test results and community feedback, and devise a set of use cases applicable to SSP and similar (dual use) digital engineering environments and workflows.

PHASE III DUAL USE APPLICATIONS: Transition the data integrator for Navy use by deploying the software on SSP's "Blue" digital engineering environment. Support user testing in accordance with the use cases developed in Phase I and Phase II, implementing improvements in the tool based on user feedback, and providing product documentation, including installation and user guides. Successful deployment on the SSP Blue digital engineering environments will demonstrate dual use since the target data source tools here (CSM, DOORS, and Windchill) are ubiquitous in many industrial/engineering sectors such as aerospace, automotive, agriculture, mining, and oil/gas.

### REFERENCES:

1. Noy, Natalya F. and McGuinness, Deborah L. "Ontology Development 101: A Guide to Creating Your First Ontology." May 11, 2021. [https://protege.stanford.edu/publications/ontology\\_development/ontology101-noy-mcguinness.html](https://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html).
2. Cruz, Isabel F. and Xiao, Huiyong. "The Role of Ontologies in Data Integration." Journal of Engineering Intelligent Systems, 13(4), December 2005. <https://www.cs.uic.edu/~advis/publications/dataint/eis05j.pdf>.
3. Protégé ontology and knowledge management system. <https://protege.stanford.edu/>.

KEYWORDS: Digital engineering; model-based engineering; model-based systems engineering; semantically-driven data integration; ontology; digital thread; data integration; semantic analysis.

## VERSION 8

N221-078 TITLE: Split Ratio Fine-Tuning Feature for Integrated Optical Circuits in Interferometric Fiber-Optic Gyroscopes

OUSD (R&E) MODERNIZATION PRIORITY: Nuclear

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 the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a new feature for Y-branch dual phase modulator integrated optical circuits (IOC) that enables fine tuning of optical power splitting ratio after assembly.

DESCRIPTION: The performance requirements for strategic-grade inertial sensors based on optical interferometry continue to become more stringent, necessitating continued innovation for optical component technologies. For example, the interferometric fiber-optic gyroscopes (IFOGs) used in inertial navigation systems for fleet ballistic missile (FBM) submarine applications require unprecedented precision, characterized in terms of long-term bias stability, scale factor linearity, angle random walk performance, etc. [Ref. 1]. A key component in these types of sensors is the integrated optical circuit (IOC). The IOC is typically comprised of Y-branch dual phase modulators based on waveguides and electrodes formed on the surface of a crystal such as lithium niobate, and assembled (pigtailed) to optical fiber (one input and two output fiber ports) [Ref 2]. The non-ideal behaviors of these IOCs are well known, and the precision of the parent inertial sensors is limited by this non-ideal behavior. Of particular concern is the optical power splitting ratio between the two output ports. Ideally the split ratio of the IOC should be precisely a 50%/50% even divide, both intrinsic to the Y-branch and after fiber pigtailling. However, manufacturing tolerances typically limit the actual IOC split ratio to a small but nonetheless significant percentage offset, and further limitations on the precision of fiber splicing the IOC into the IFOG optical circuit typically compounds split ratio offset. This SBIR topic relates to advanced lithium niobate IOCs for IFOGs with 1550 nm operating wavelength that shall include a new feature for fine-tuning the split ratio, with precision as good or better than 0.1%, after assembly. The fine tuning shall be achieved by controlling the optical loss of one output port relative to the other, and this control may be implemented by a new feature of the lithium niobate chip, the fiber, or an additional subcomponent. The new feature shall have negligible impact on other IOC design and performance criteria such as overall size, overall optical insertion loss, polarization extinction ratio (PER), and switching voltage-length product ( $V_{pi-L}$ ).

PHASE I: Perform a design and materials study aimed at a new feature for fine-tuning the split ratio of a lithium niobate IOC after assembly. The new feature shall be compatible with IOCs having either annealed proton exchange (APE) or reverse proton exchange (RPE) waveguides with 1550 nm operating wavelength. The study must assess performance criteria and consider all aspects of device fabrication. The study shall include a preliminary assessment of long-term environmental stability assuming a design life of 30 years at 50°C based on a materials physics analysis, including Mean Time Between Failure (MTBF), Mean Time to Failure (MTTF) and Failure In Time (FIT) values, along with identification of the assumptions, methods, activation energy, and confidence levels associated with these values. The study shall justify the feasibility/practicality of the approach for achieving split ratio fine-tuning with

## VERSION 8

0.1% precision with negligible impact on other IOC design and performance criteria including overall size, overall optical insertion loss, polarization extinction ratio, and switching V<sub>pi</sub>-L. The study shall estimate the effects of the new split ratio fine-tuning feature on IOC design and performance criteria relative to a control prototype design that does include the new feature. The Phase I Option if exercised, will include the initial design specifications and capabilities description to build prototype solutions in Phase II, as well as a test plan for an accelerated aging study (minimum 5 year real-time equivalent) to be conducted in Phase II.

PHASE II: Based on the Phase I results, design, fabricate, and characterize six (6) prototype IOCs, complete with fiber-optic pigtails and electrical connectorization suitable for incorporation into test beds for interferometric inertial sensors. Characterization must comprise of evaluation of split ratio tunability, as well as electrical measurements including half-wave voltage (V<sub>pi</sub>), frequency response and residual intensity modulation (RIM), and optical measurements including optical insertion loss, chip PER, optical return loss (ORL) or coherent backscatter, and wavelength dependent loss (WDL). An accelerated aging study involving IOCs at elevated temperatures under vacuum must be performed to develop a predictive model of long-term environmental stability. The prototypes should be delivered by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Based on the prototypes developed in Phase II, continuing development must lead to productization of IOCs suitable for interferometric inertial sensors. While this technology is aimed at military/strategic applications, phase modulators are heavily used in many optical circuit applications, including in telecom industry hardware. A phase modulator with split ratio tunability is likely to bring value to many existing commercial applications, such as optical internet, satellite communications, and electric field sensing. Also, technology meeting the needs of this topic could be leveraged to bring IFOG technology toward a price point that could make it more attractive to the commercial markets for land, sea, and aerial systems, including unmanned and autonomous systems.

### REFERENCES:

1. Adams, Gary, and Gokhale, Michael. "Fiber optic gyro based precision navigation for submarines." Proceedings of the AIAA Guidance, Navigation and Control Conference, Denver, CO, USA, August 2000: 2–6. <https://arc.aiaa.org/doi/pdf/10.2514/6.2000-4384>.
2. Wooten, Ed L. et al. "A review of lithium niobate modulators for fiber-optic communications systems," IEEE Journal of Selected Topics in Quantum Electronics 6, January 2000: 69-82. <https://ieeexplore.ieee.org/document/826874>.

KEYWORDS: Integrated Optical Circuit; Phase Modulator; Lithium Niobate; Waveguides; Inertial Sensor; Fiber-optic Gyroscope

## VERSION 8

N221-079 TITLE: Low-Loss, Low-Aberration, Numerical Aperture-Matched Microlens Arrays to Improve Coupling Efficiency onto Photonic Imaging Devices.

OUSD (R&E) MODERNIZATION PRIORITY: Quantum Science

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 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 microlens arrays to improve coupling of light onto photonic imaging devices by reducing aberrations and improving mode matching to the collection aperture.

**DESCRIPTION:** This SBIR topic seeks to develop and fabricate microlens arrays optimized for coupling power onto a photonic imaging device to enable enhanced performance of a variety of integrated photonics systems. Most photonic imaging devices collect light and couple it into photonic integrated circuits (PIC) using grating couplers [Refs 1-2], but photonic chips can suffer significant loss from absorption and scattering within PICs. It is critical that enough light reaches the detectors for the scene to be imaged, so it is necessary to maximize the amount of usable light that couples onto the photonic chip.

Because photonic grating couplers are generally rectangular, they have axis-dependent numerical aperture (NA). The NA is greater along the shorter rectangular axis and smaller along the longer rectangular axis. Furthermore, the grating efficiency and angle of collection are both wavelength dependent. Current Commercial Off the Shelf (COTS) microlens arrays have axis-independent numerical apertures, chromatic aberrations, and also high surface roughness; making them sub-optimal for coupling light onto the chip. Integrating a low-aberration, achromatic, axis-dependent NA and pitch-matched microlens array with photonic imagers would increase the optical throughput by approximately 10 dB, increasing the detected signal.

**PHASE I:** Perform a design and fabrication analysis to assess the feasibility of producing low-aberration, achromatic in the near-infrared (across 700 – 900 nm) microlens arrays for integration with photonic imaging systems. The design must be able to accommodate NA values that differ significantly along two axes (for example: an NA of 0.045 along one grating axis, 0.15 in the other), while focusing light into a spot on a single plane. The thickness of the microlens array, including any substrate, must be less than 1.5mm. Array pitch should be in the 60-100 um range. Include the expected NA tolerances along both axes (no greater than 2%), pitch tolerance (within 1 micron of expected location, across 200 lenslets), and achromaticity over the near-infrared wavelength range (no more than 15 nm short of bounds). Develop a detailed plan of fabrication that identifies risks and risk mitigation strategies. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build prototype solutions in Phase II.

**PHASE II:** Fabricate and characterize twenty (20) prototype microlens arrays, measuring at least 1 cm by 1 cm square, with a thickness of less than 1.5 mm, to be integrated with a photonic imaging system. Surface roughness-induced loss, achromaticity, and NA should be characterized and should fall within

## VERSION 8

1% of the values determined from the work in Phase I. Evaluate the device's thermal, vibration, and radiation sensitivities by performing tests in accordance with MIL-STD-883L [Ref 3].

Produce a final report that includes a discussion of potential near-term and long-term development efforts that would improve the technology's performance and/or ease of fabrication. It will also include an evaluation of the cost of fabrication and how that might be reduced in the future. The prototypes should be delivered by the end of Phase II.

**PHASE III DUAL USE APPLICATIONS:** Based on the prototypes and continual advancement of photonics, grating-matched microlens arrays should lead to the production of a design suitable for use in integrated photonic imaging and photonic sensing applications. Support the Navy in transitioning the technology to Navy use. The lenslet arrays will be evaluated through optical characterization and testing with prototype devices. The end product technology could be leveraged to bring photonic imaging and sensing towards a more mature state with a lower Size, Weight, and Power (SWaP) profile that could make it more attractive to biomedical, navigation, and vehicle autonomy commercial markets.

### REFERENCES:

1. Clevenson, Hannah A. et al. "Incoherent Light Imaging Using an Optical Phased Array", Applied Physics Letters, Vol. 116, Issue 3, 031105 (2020). <https://doi.org/10.1063/1.5130697>.
2. E. H. Cook et al., "Polysilicon Grating Switches for LiDAR," in Journal of Microelectromechanical Systems, vol. 29, no. 5, pp. 1008-1013, Oct. 2020, doi: 10.1109/JMEMS.2020.3004069.
3. MIL-STD-883L, Department of Defense Test Method Standard: Microcircuits (16-SEP-2019). [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883L\\_56323/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-883L_56323/).

**KEYWORDS:** photonic imaging; microlens array; photonic integrated circuits; numerical aperture; low-aberration, achromatic

## VERSION 8

N221-080 TITLE: Development of a Time-Triggered Ethernet Intellectual Property Block

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR);Hypersonics;Space

TECHNOLOGY AREA(S): Air Platforms; Battlespace Environments; 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 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 implementation of a Time-Triggered Ethernet (TTEthernet) Intellectual Property (IP) block for hard real-time control applications in next-generation avionics architectures.

DESCRIPTION: Currently, non-deterministic Ethernet (as defined by IEEE 802.3 [Ref 3]) is utilized in many of the Navy's weapon and avionics systems, including hypersonics. While commonly used for non-critical data, non-deterministic Ethernet does not provide temporal guarantees on data delivery needed for safety-critical real-time control. This often necessitates the use of a secondary, supplemental, real-time network for safety-critical applications. In high threshold, event-driven applications, such as hypersonics, non-deterministic Ethernet limits data rates. The data network in this weapon system plays a crucial role in error prevention and failure recovery, and in high-speed systems, time critical data is vital for mission success. Developing an event-driven, real-time deterministic Ethernet system has the potential to accommodate the full spectrum of traffic criticality levels required in hard real-time applications such as hypersonic systems, as well as a variety of aerospace systems. Time-Triggered Ethernet (TTEthernet, as defined by SAE AS6802 [Ref 2]) unifies real-time and non-deterministic traffic into a single coherent Ethernet-based communication network. Foreign-based TTEthernet implementations are already in use on NASA's Orion spacecraft (NASA Spinoff) [Ref 1].

The U.S. Navy desires a U.S.-based implementation of trusted TTEthernet available in the form of an IP block for inclusion in future aerospace microelectronics. The implementation should consist of the following:

- Must comply with SAE AS6802 (Society of Automotive Engineers)
- Must be operable with non-deterministic Ethernet networks ( IEEE 802.3 (IEEE))
- Must include both Endpoint and Network Switch implementations
- Be capable of 10/100/1000 Mbit/sec operations
- Be available in either Verilog, SystemVerilog, or VHDL
- Be fully synthesizable in at least two technology nodes, examples include Intel 22FFL, GlobalFoundries 12LP, and Skywater 90RH
- Must include a verification suite
- Must include full government purpose rights to all design and verification IP
- Must include 32-bit user application layer compliant with RISC-V and ARM processor core bus standards such as AXI4-ST
- Be certifiable

Work produced in Phase II may become classified. 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

## VERSION 8

Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor 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: Provide a proof-of-concept IP block that implements either Endpoint or Switch functionality and is capable of at least 10Mbit/sec operation with a path towards synthesis on at least one of the above mentioned technology nodes. This IP block must also include an initial verification suite.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Provide the TTEthernet IP block as specified in the Description and fabricate a validation Integrated Circuit (IC) containing the IP block on at least one of the above-mentioned technology nodes. Both the IP block and fabricated IC will be made available to the U.S. Navy. The developed prototype shall meet all performance and technical requirements listed in the Description section above. Furthermore, the prototype shall be either benchtop tested or tested in a relevant environment such as a sounding rocket.

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 resulting IP block to deployment on at least one future IC developed by the Navy and/or its contractors. This likely includes radiation-hardened ICs used in hypersonic applications. Work with the government to validate and qualify the resulting technology via sounding rocket campaigns, HWIL validation simulations, and eventually all-up flight testing. Developing an event-driven, real-time deterministic Ethernet system has the potential to accommodate the full spectrum of traffic criticality levels required in hard real-time applications such as hypersonic systems, as well as a variety of aerospace systems. Additionally, commercial rocket and space sectors could utilize this technology in their rockets/spacecraft systems.

### REFERENCES:

1. NASA Spinoff, "Time-Triggered Ethernet Slims Down Critical Data Systems," . [https://spinoff.nasa.gov/Spinoff2018/t\\_4.html](https://spinoff.nasa.gov/Spinoff2018/t_4.html).
2. Society of Automotive Engineers, "Time-Triggered Ethernet AS6802," <https://www.sae.org/standards/content/as6802/>.
3. IEEE, "802.3-2018 - IEEE Standard for Ethernet," [https://standards.ieee.org/standard/802\\_3-2018.html](https://standards.ieee.org/standard/802_3-2018.html).

KEYWORDS: Time-Triggered Ethernet; TTEthernet; Hypersonics; Avionics; Time-critical, Real-Time Systems; Data Rates

## VERSION 8

N221-081 TITLE: Development of an Aerothermal Modeling and Simulation Code for Hypersonic Applications

OUSD (R&E) MODERNIZATION PRIORITY: General Warfighting Requirements (GWR);Hypersonics

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

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

**OBJECTIVE:** Develop a high fidelity modeling and simulation code that can be used to accurately model the physics associated with aerothermal flow, high temperature material response, and thermal protection system (TPS) design for hypersonic flight systems. Emphasis should be placed on non-linear structure analysis, material contact, and thermal conduction and radiation analysis between material interfaces.

**DESCRIPTION:** The extreme operating environments of hypersonic flight systems require ultra high temperature capable aeroshell materials that have robust loading capability to ensure mission survivability. These aeroshell materials experience very challenging aerothermal and thermo-structural environments during flight which is very challenging to predict. There are a number of legacy and commercial codes that have proven to be accurate when calculating aeroheating effects such as nosetip, leading edge, and missile body heating and material ablation, which include physics such as inviscid and viscous flow, shock structure, and boundary layer transition. Likewise, there are a many Finite Element Codes that are excellent for calculating 3D structural response to understand material loading capability including non-linear, transient thermostructural response of a full size Thermal Protection System (TPS) component. However these Finite Element Analyses (FEA) codes are not capable of adapting to the transient aerothermal flow physics that aeroshell materials experience during a hypersonic flight environment such as calculating shape change to the missile body as a function of time. Current modeling and simulation techniques for Navy TPS systems utilize these tools by making assumptions and manually mapping results from aerothermal specific codes to an FEA simulation, which is very time consuming and costly. There is a need for an improved methodology for coupling aerothermal codes to these FEA solvers to provide an integrated simulation capability.

The government is seeking a solution to bring these tools together to provide a high fidelity aerothermal and TPS design tool that can automate the process of coupling aerothermal physics and material response into FEA thermo-structural models for a complete aero-thermal-mechanical survivability analysis across Navy hypersonic flight trajectories.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor 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



## VERSION 8

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 proof of concept, knowledge and understanding of codes that provide accurate aerothermal and heating codes to prove the applicability to Navy hypersonic flight systems. A clear concept on how to demonstrate that the outputs from the aerothermal codes can be brought in as inputs to the FEA software to update the 3D structural model as a function of time. Decide the best method to apply the coupling of the aerothermal and FEA codes (relevant codes will be provided upon Phase I award) for the most robust and feasible solution (e.g., sub routine, script interface, or a completely separate executable/file). Demonstrate software and sequence diagrams of how the tool(s) will calculate results. Analysis will be performed to show feasibility of aerothermal and FEA solvers functionality. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Develop a prototype utilizing representative vehicle geometry and flight trajectories as provided by the government and also based on the results of Phase I and the Phase II Statement of Work (SOW). The developed model should consist of two concepts: computational fluid dynamics (CFD) and a heat transfer portion. Phase II will include utilizing classified vehicle geometry and flight trajectories to provide benchmark testing versus as-flown Navy hypersonic flight data. In Phase II, verification and validation (V&V) should be in the scope of work. Compare the prototype with bench test and flight test data.

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

**PHASE III DUAL USE APPLICATIONS:** Support the Navy in transitioning the technology to Navy use. The final product shall be a delivered code, package outlining the script/functionalities of the developed code and documentation for the model. The final design will be in consideration for being transitioned into the Navy's Conventional Prompt Strike (CPS) hypersonic weapon system modeling and simulation tools. A suitable code solution, verified with benchmark testing with as-flown data is required for the future toolset to optimize vehicle design. In addition, this technology can be transitioned for use in analyzing other Navy and Air Force hypersonic and ballistic weapon systems for optimization of vehicle design. Commercially, future hypersonic transportation vehicles and high speed aerospace systems would benefit from this code solution as it would provide valuable data for design optimization of the mentioned vehicles.

### REFERENCES:

1. Blades, E.L; Shah, P. N.; Nucci, M.; Miskovish, R. S. "Demonstration of Multiphysics Analysis Tools on Representative Hypersonic Vehicle Structures." Boston, Massachusetts: ATA Engineering, Inc., 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 11 April 2013. <https://arc.aiaa.org/doi/pdf/10.2514/6.2013-1746>.
2. Tauqeer ul Islam Rizvi, S; Linshu He; Dajun Xu. "Optimal Trajectory Analysis of Hypersonic Boost-glide Waverider with Heat Load Constraint." Aircraft Engineering and Aerospace Technology, ISSN:0002-2667, 5 July 2015. <https://www.emerald.com/insight/content/doi/10.1108/AEAT-04-2013-0079/full/html>.
3. Shih, Peter; Zwan, Allen; Kelley, Michael. "Thermal Protection System Optimization for a Hypersonic Aerospace Vehicle." San Diego, California: General Dynamics Convair Division, 17 August 2012. <https://arc.aiaa.org/doi/abs/10.2514/6.1988-2739>.

**KEYWORDS:** Hypersonics; Modeling and Simulations Code; Aerothermal Analysis; Thermal Protection System; Ablation; Non-linear Structure Analysis; Radiation Analysis

## VERSION 8

N221-082      TITLE: Integrated Complementary Metal Oxide Semiconductor Nuclear Event Detector for System on a Chip Applications

OUSD (R&E) MODERNIZATION PRIORITY: Nuclear

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 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 the techniques and circuitry needed to deploy a fully integrated Complementary Metal Oxide Semiconductor (CMOS) Nuclear Event Detector (NED). Additional objectives include the development of an all-digital interface to enable increased security and circumvention and recovery concepts of operations (CONOPS) flexibility.

DESCRIPTION: Nuclear Event Detectors are used in strategic systems to detect when a preset rate of prompt dose is deposited on the detector. Traditionally Nuclear Event Detectors are Hybrid type devices that incorporate a P-Type Intrinsic N-Type (PIN) semiconductor diode, which acts as a photocurrent collection volume which is then mated with other electronic components that appropriately bias the diode and detect when a set level of photo current is exceeded. These hybrid designs can be expensive and unwieldy – it would be highly desirable if a NED circuit could be fully incorporated into any CMOS Application Specific Integrated Circuit (ASIC). Additionally, an ASIC implementation would facilitate the inclusion of an all-digital threshold set point. This NED concept should be deployable into any CMOS Silicon on Oxide or bulk process. Since most commercial foundries do not allow modifications to the process flow, the expectation is that no modifications to the CMOS process recipe are allowed and adherence to process design rules must be followed. The challenge will be to fully integrate both the needed collection volume and related circuitry onto one CMOS die.

PHASE I: Develop a concept design for a fully integrated CMOS NED. Design concepts can be demonstrated in a Defense Microelectronics Activity (DMEA) certified trusted CMOS foundry. Simulation results utilizing industry standard Integrated Circuit Simulation Tools are expected to show concept feasibility including fidelity of the detection set point as well as the ability of the detection circuit itself to operate correctly in a prompt dose environment. A discussion of the technology volume limitations should be included in the Phase I study. Industry benchmarks of commercially available Nuclear Event Detectors should be used. For example, the HSN-3000 Nuclear Event Detector design benchmarks include [Ref 1]:

- Dose Rate (operate-through):  $1 \times 10^{12}$  rad(Si)/sec
- Total Dose Performance:  $1 \times 10^6$  rad(Si)
- Neutron Fluence:  $5 \times 10^{13}$  n/cm<sup>2</sup>
- Approximate Detection Range:  $2 \times 10^5$  -  $2 \times 10^7$  rad(Si)/sec

The Phase I Option, if exercised, will include the initial design specifications, selected foundry, and capabilities description to build a prototype solution in Phase II.

## VERSION 8

PHASE II: The concept design and specifications from Phase I will be fully developed as a standalone Integrated Circuit (IC). Final circuit design viability will be demonstrated by simulations across process corners, the standard military temperature range, and modeled strategic radiation environments. The resulting design database will be used to fabricate a minimum of twenty-five (25) prototype die. All design schematics and layout files are part of the required deliverable. The prototypes should be delivered by the end of Phase II. These prototype parts will be tested and evaluated across environments by the SBIR sponsor [Ref 2].

PHASE III DUAL USE APPLICATIONS: The final version of the NED (in its standalone form) will be productized at the selected DMEA certified trusted foundry and made available to Strategic Programs. This final design should be suitable for either fabrication as a standalone NED or the design database could be leveraged by Strategic programs for the deployment into a larger SoC. Having the option to integrate the NED into program required ICs would reduce component costs as well as potentially provide additional detection coverage due to the increased number of locations in the weapon system the NED will reside.

### REFERENCES:

1. Data Device Corporation (DDC), HSN-3000 Device Features Web Page: [www.ddc-web.com/en/nucleareventdetectors-1/hsn-3000](http://www.ddc-web.com/en/nucleareventdetectors-1/hsn-3000).
2. Hash, G.L. and Schwank, J.R. et al: "Radiation characterization of a Monolithic nuclear event detector." Workshop record 1992, IEEE Radiation Effects Data Workshop, <https://ieeexplore.ieee.org/document/247320>.

KEYWORDS: NED; Nuclear Event Detector; collection volume; prompt dose; foundry; radiation environment

# VERSION 8

N221-083 TITLE: Variable Conductance Thermal Management Technology

OUSD (R&E) MODERNIZATION PRIORITY: Quantum Science

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 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 technology that dynamically adjusts the thermal conductivity between a sensor and its environment to assist in maintaining a stable temperature with minimal power draw. The technology should be compact, robust, and easily adaptable to a variety of sensor shapes, sizes, and internal heat loads.

**DESCRIPTION:** For a wide variety of sensing systems, a stable temperature is crucial to minimize systematic errors in the measurement output; however, a fieldable sensor is often expected to operate through extreme environmental temperature swings that often exceed 100°C. To combat this temperature swing, a sensor is stabilized by a thermal management solution. Reference 1 contains a summary of a variety of such solutions. Of these, the most common options for the high-precision inertial sensors of primary interest are thermoelectric coolers or simple heaters to actively control the temperature. But while the efficiency of these options are good when the sensor temperature setpoint and the ambient temperature are similar ( $\Delta T \sim 0^\circ\text{C}$ ), the power draw becomes large when those two temperatures differ significantly ( $\Delta T \gg 1^\circ\text{C}$ ).

Variable conductance heat pipes (VCHP) suggest an interesting possibility. The thermal conductance of these devices passively changes depending on the temperature of the environment. With a careful selection of materials and dimensions, the VCHP can provide an extremely small thermal conductance when the environment is much colder than the sensor, and a high conductance when the environment and sensor are similar in temperature [Ref. 2]. As a direct consequence of this variable conductance, the demand on the active portion of the thermal stabilization is reduced, resulting in a much lower overall power draw. The promise of this variable conductance has been successfully demonstrated in designs intended for lunar landers and rovers immersed in the large lunar daytime/nighttime temperature swings [Ref. 2] And yet VCHPs are not a universal solution. In particular, they are rigid devices that require highly customized designs depending on the sensor size and shape.

The proposed variable conductance solution (VCS) will comprise an alternative material or technology that has the benefits of a variable conductance, but is more easily adaptable to unusual shapes, including a combination of flat and curved surfaces. Table 1 outlines three model environments and a model sensor. The VCS will act as the interface between the sensor and environment, limiting the temperature swing of the sensor to the specified range even as the environment's temperature varies much more widely.

Table 1. Proposed Variable Conductance Solution (VCS) Scenarios

	Scenario 1	Scenario 2	Scenario 3
--	------------	------------	------------

## VERSION 8

Environment temperature range	-10°C to 40°C	20°C – 85°C	-40°C to 85°C
Nominal sensor temperature setpoint	55°C	50°C	25°C
Sensor temperature deviation from nominal setpoint over environmental temperature range after application of the VCS*	$\pm 5^\circ\text{C}$		
Sensor steady state heat load	Threshold: 1W – 10W Objective: 1W – 50W		
Sensor Shape	Must include at least one curved and one flat surface (specifically, the sensor shape could be a cylinder or hemisphere).		
Sensor Volume	Threshold: < 25L Objective: < 2.5L		
Additional volume allotted to the VCS	< 10% sensor volume		
VCS power draw	< 1W		

\*In a fieldable device, a secondary active temperature stabilization system will provide the final stabilization < 1°C.

In these configurations, a range of model sensor heat loads and volumes are provided. A single instance of the VCS does not need to accommodate all of these loads and sizes simultaneously. Instead, the system can be designed for a single heat load and a single shape; however, proposed solutions must be sufficiently flexible in design and fabrication to be easily adaptable to other shapes and heat loads.

PHASE I: Perform a design and materials study to assess the feasibility of the selected technology and its ability to meet the goals of one of the scenarios in Table 1. For the chosen scenario, the study will include:

- An estimate and justification of the dependence of the thermal conductivity on the environmental temperature.
- An estimate and justification of the range of sensor heat loads the system can accommodate while still meeting temperature stability specification.
- An evaluation of the technology's SWaP that would be built for Phase II.
- A discussion of the fabrication process including an assessment of risks and risk mitigation strategies.
- A discussion of the technology's compatibility with the other two scenarios not selected.
- A discussion of the technology's rate of adjustment
- A discussion of the technology's radius of curvature limitations.

## VERSION 8

- A discussion of the technology's compatibility with shock/vibration mounts.
- A discussion of the technology's sensitivity with respect to orientation to gravity.
- A discussion of the technology's ability to be adapted to different sensor shapes, including smaller sensor sizes, concave curves, and tight radii of curvature.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build prototype solutions in Phase II, as well as a proof-of-principle demonstration of thermal conductivity variation of the proposed technology.

PHASE II: Fabricate and test three (3) prototypes of the design developed in Phase I, ? one for each sensor shape. A mock sensor can be constructed from a simple shell with an internal heat load and sufficient thermal sensors to capture potential thermal gradients. The completed prototypes will undergo testing at a minimum of five temperatures that completely span the specified environmental temperature range. the technology's thermal conductivity and power draw will be reported. At each temperature, the mock sensor's steady state temperature and settling time constant will be reported for sensor heat loads that span the range specified. The final report will include a discussion of potential near-term and long-term development efforts that would improve the technology's performance, SWAP, and/or ease of fabrication. It will also include an evaluation of the cost of fabrication and how that might be reduced in the future. The prototypes should be delivered by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Continue development to assist the Government in applying the VCS to a fieldable, thermally stabilized inertial sensor. As thermal management is also an important consideration for high-precision sensors outside of military applications, development should continue to assist interested commercial parties. Geological resource exploration and monitoring require ruggedized sensors that would benefit from this technology. It could also be applied in medical systems as those often have stringent thermal and power draw requirements. More generally, thermal management is an important consideration in areas as wide ranging as solar cells, rechargeable batteries for electric vehicles, and data centers.

### REFERENCES:

1. Lupu, A.G., et al. "A review of solar photovoltaic systems cooling technologies." IOP Conference Series: Materials Science and Engineering. Vol. 444. No. 8. IOP Publishing, 2018.  
<https://iopscience.iop.org/article/10.1088/1757-899X/444/8/082016/pdf>.
2. Anderson, William, et al. "Variable conductance heat pipes for variable thermal links." 42nd International Conference on Environmental Systems. 2012.  
<https://arc.aiaa.org/doi/pdf/10.2514/6.2012-3541>.

KEYWORDS: Thermal management; power draw; environmental temperature; sensors; inertial sensors; thermal conductance; materials

## **VERSION 8**

~~N221-084~~

TITLE: [Navy has removed topic N221-084 from the 22.1 SBIR BAA]

## VERSION 8

N221-085      TITLE: Integration Strategy for Complementary Metal Oxide Semiconductor-based Terahertz Spectroscopy Systems

OUSD (R&E) MODERNIZATION PRIORITY: Nuclear

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 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 prototypes that achieve low-loss coupling of sub-THz radiation (frequency range: 200-300 GHz) between a Complementary Metal Oxide Semiconductor (CMOS)-based structure and a compact, hermetically-sealed waveguide. The integration strategy must minimize size, weight, and power (SWaP) of the combined CMOS plus waveguide system; and must be robust to environmental instabilities such as ambient temperature changes.

**DESCRIPTION:** In the past decade there has been significant interest in and development of THz-based instruments for applications including imaging (e.g., non-ionizing medical diagnostics, security screening), molecular spectroscopy (chemical detection and precision timekeeping), extreme wideband communications, and radar [Ref 1]. Recently, advanced high-speed CMOS integrated circuit designs have led to transmitters (Tx) and receivers (Rx) in the THz regime with vastly reduced SWaP relative to competing technologies [Refs 2, 3]. In addition, THz waveguides have been miniaturized via microfabrication techniques [Ref 4]. When coupled to a millimeter-scale waveguide filled with a molecular gas, these CMOS-based Tx/Rx designs can form the basis of an extremely low-SWaP spectroscopy platform for use in DoD-relevant applications (e.g., a chip-scale clock [Ref 5]). This architecture also contains no electro-optic components, making it much more resilient to radiation effects that are known to degrade the performance of lasers, photodetectors, etc. As a result, CMOS-based THz spectroscopy systems are of great utility in DoD applications that require a combination of low-SWaP and radiation hardness.

Despite the recent CMOS design progress, significant additional development is needed to fully integrate a low-SWaP, low-cost, manufacturable spectroscopy instrument. Given the scalable advantages of CMOS-based manufacturing, this effort is anticipated to yield units that match the SWaP of modern miniaturized atomic systems (e.g. chip-scale atomic clock; ~100mW, 15 cm<sup>3</sup>) but at > 10X reduced cost (hundreds of dollars rather than thousands of dollars per unit) Some development considerations include:

1. The coupling efficiency between the CMOS Tx/Rx and the waveguide structure must be maximized without introducing stringent alignment requirements that introduce high assembly costs.
2. The waveguide containing the molecular sample must be designed to maximize its length while minimizing its volume and loss properties.
3. The mechanical coupling between the CMOS and waveguide must be robust enough to operate in a shock/vibe/temperature range environment consistent with DoD applications.

Design concepts must be communicated in sufficient detail that their approach can be adapted straightforwardly to any frequency in the specified range of 200-300 GHz. The performance targets in



## VERSION 8

Table 1 must be achieved through the production of an integrated prototype. This does not require the waveguide to be sealed with a specific molecular species, it does require that the waveguide incorporates a hermetic seal.

Table 1: Performance targets

Parameter Value

CMOS-to-Waveguide coupling loss: < 3 dB per interface

Waveguide loss: < 0.5 dB/cm

Waveguide dimensions Goal: maximize length within a 1 cm<sup>3</sup> volume constraint; minimum acceptable length = 3 cm

Integrated CMOS + waveguide volume: < 2 cm<sup>3</sup>

Temperature Sensitivity: < 3 dB change in end-to-end coupling over temperature range of -20° to +85°Celsius

PHASE I: Perform a design study that includes a trade space analysis and modeling of system performance with sufficient completeness and fidelity to demonstrate the feasibility to achieve the performance targets in Table 1. This includes a design of a CMOS device with sufficient test structures to demonstrate the required CMOS-to-waveguide coupling efficiency, the waveguide, and the details of how it will be fabricated, and the mechanical structure and assembly procedure for integration. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II. A detailed test and evaluation plan is required in order to assess the hardware developed in Phase II.

PHASE II: Finalize designs of the CMOS-to-waveguide coupling strategy (CMOS device plus waveguide input/output), the waveguide structure, and the mechanical approach for integration. Produce and deliver five (5) integrated CMOS Tx/Rx structures plus waveguide prototypes and evaluate them against the performance targets in Table 1. A detailed test report must be delivered that clearly documents test procedures, performance vs. targets, hermetic seal leak rates, and a path forward to meet any targets not achieved. The prototypes should be delivered by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: The prototypes developed in Phase II establish a path to integrating sensors based on THz spectroscopy. Further development must lead to fully miniaturized systems that robustly operate in shock and vibration environments relevant to Navy missions. In addition to the metrics demonstrated by the Phase II prototypes, this goal will require hermetically sealing a target gas species in the waveguide structure, incorporating all spectroscopic functionality (e.g., THz generation, transmission, reception, and signal processing) onto the CMOS chip, and generating derived sensor outputs. Support the Navy to ensure that the integration strategy can be included in future system development efforts that are targeted at specific applications. For example, a low-SWaP, low-cost, radiation-hardened clock based on a THz frequency reference would find wide usage in military, space and commercial applications that require a stable and precise timing source. Examples include navigation and communications in GPS-challenged environments, communication via satellite constellations, high-speed network synchronization, and undersea oil exploration via reflection seismology.

### REFERENCES:

1. Pawar, A.Y.; Sonawane, D.D.; Erande, K.B. and Derle, D.V., "Terahertz technology and its applications," *Drug Invention Today*, Vol. 5, no. 2, pp. 157-163, 2013.  
<https://doi.org/10.1016/j.dit.2013.03.009>.
2. Lee, T. "Terahertz CMOS integrated circuits," 2014 IEEE International Symposium on Radio-Frequency Integration Technology, Hefei, China, 2014.  
<https://doi.org/10.1109/RFIT.2014.6933268>.

## VERSION 8

3. Fujishima, M. and Amakawa, S. "Design of Terahertz CMOS Integrated Circuits for High-Speed Wireless Communication", Institute of Engineering and Technology, 2019.  
<https://doi.org/10.1049/PBCS035E>.
4. Ermolov, V.; Lamminen, A.; SaariLahti, J.; Walchli, B.; Kantanen, M. and Pursula, P. "Micromachining integration platform for sub-terahertz and terahertz systems," International Journal of Microwave and Wireless Technologies, Vol. 10, no. 5-6, pp. 651-658, 2018.  
<https://doi.org/10.1017/S175907871800048X>.
5. Wang, C.; Yi, X.M.J.; Kim, M.; Wang, Z. and Han, R. "An on-chip fully electronic molecular clock based on sub-terahertz rotational spectroscopy," Nature Electronics, Vol. 1, no. 7, pp. 421-427, 2018. <https://doi.org/10.1038/s41928-018-0102-4>.

KEYWORDS: Terahertz; Transmitters; Receivers; Waveguides, Spectroscopy; CMOS; Radiation Hardness

## **VERSION 8**

~~N221-086~~

[Navy has removed topic N221-086 from the 22.1 SBIR BAA]