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

IMPORTANT

- **The following instructions apply to STTR topics only:**
    - **N23A-T001 through N23A-T029**
- **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.**
- 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.
- 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. Additional information on DON's mission can be found on the DON website at 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 Program Manager of the DON STTR Program is Mr. Steve Sullivan. 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
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 (https://www.dodsbirsttr.mil/submissions)

		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	DSIP Support via email at dodsbirsupport@reisystems.com
Navy-specific BAA instructions and forms	Always	Navy SBIR/STTR Program Management Office usn.pentagon.cnr-arlington-va.mbx.navy-sbir-sttr@us.navy.mil

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

Topic Numbers	Point of Contact	SYSCOM	Email
N23A-T001 to N23A-T008	Ms. Kristi Wiegman	Naval Air Systems Command (NAVAIR)	navair.sbir@navy.mil
N23A-T009 to N23A-T014	Mr. Jason Schroepfer	Naval Sea Systems Command (NAVSEA)	NSSC_SBIR.fct@navy.mil
N23A-T015 to N23A-T029	Mr. Steve Sullivan	Office of Naval Research (ONR)	usn.pentagon.cnr-arlington-va.mbx.onr-sbir-sttr@us.navy.mil

PHASE I SUBMISSION INSTRUCTIONS

The following section details requirements for submitting a compliant Phase I Proposal to the DoD SBIR/STTR Programs.

(NOTE: Proposing small business concerns 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). Proposing small business concerns 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 means will be disregarded. Proposing small business concerns submitting through DSIP for the first time will be asked to register. It is recommended that small business concerns 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 the proposal 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.
  - Work proposed for the Phase I Base must be exactly six (6) months.
  - Work proposed for the Phase I Option must be exactly six (6) months.
- Additional information:
  - It is highly recommended that proposing small business concerns use the Phase I proposal template, specific to DON topics, at 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, proposing small business concerns 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 the proposal 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.
  - For Phase I a minimum of 40% of the work is performed by the proposing small business concern, and a minimum of 30% of the work is performed by the single research institution. The percentage of work is measured by both direct and indirect costs. To calculate the minimum percentage of effort for the proposing small business concern the sum of all direct and indirect costs attributable to the proposing small business concern represent the numerator and the total cost of the proposal (i.e., Total Cost before Profit Rate is applied) is the denominator. The single research institution percentage is calculated by taking the sum of all costs attributable to the single research institution (identified as Total Subcontractor Costs (TSC) 1 in DSIP Cost Volume) as the numerator and the total cost of the proposal (i.e., Total Cost before Profit Rate is applied) as the denominator.
    - Proposing Small Business Concern Costs (included in numerator for calculation of the small business concern):
      - Total Direct Labor (TDL)
      - Total Direct Material Costs (TDM)
      - Total Direct Supplies Costs (TDS)
      - Total Direct Equipment Costs (TDE)
      - Total Direct Travel Costs (TDT)
      - Total Other Direct Costs (TODC)
      - General & Administrative Cost (G&A)

NOTE: G&A, if proposed, will only be attributed to the proposing small business concern.

- ☐ Research Institution (numerator for Research Institution calculation):
  - — Total Subcontractor Costs (TSC) 1
- ☐ Total Cost (denominator for either calculation)

- ○ 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).

- **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 proposing small business concerns must review and submit the following items, as applicable:
  - — **Telecommunications Equipment Certification.** Required for all proposing small business concerns. 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 proposing small business concerns 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 proposing small business concerns must review to determine applicability. In accordance with DFARS provision 252.209-7002, a proposing small business concern is required to disclose any interest a foreign government has in the proposing small business concern when that interest constitutes control by foreign government. All proposing small business concerns must review the Foreign Ownership or Control Disclosure information to determine applicability. If applicable, an authorized representative of the small business

concern 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.

- Additional information:
    - Proposing small business concerns may include the following administrative materials in Supporting Documents (Volume 5); a template is available at https://navysbir.com/links_forms.htm to provide guidance on optional material the proposing small business concern 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
    - 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, proposing small business concerns 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 DSIP submission requirements will be forwarded to the DON SBIR/STTR Programs. Prior to evaluation, all proposals will undergo a compliance review to verify compliance with DoD and DON SBIR/STTR proposal eligibility requirements. Proposals not meeting submission requirements will be REJECTED and not evaluated.

- **Proposal Cover Sheet (Volume 1).** The Proposal Cover Sheet (Volume 1) will undergo a compliance review to verify the proposing small business concern has met eligibility requirements and followed the instructions for the Proposal Cover Sheet as specified in the DoD SBIR/STTR Program BAA.

- **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. 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; the DON will only do a compliance review of Volume 3. 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 proposing small business concern has met the following requirements or the proposal 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.
- Work proposed for the Phase I Base must be exactly six (6) months.
- Work proposed for the Phase I Option must be exactly six (6) months.

- **Cost Volume (Volume 3).** The Cost Volume (Volume 3) will not be considered in the selection process and will only undergo a compliance review to verify the proposing small business concern has met the following requirements or the proposal will be REJECTED:
  - Must not exceed values for the Base ($140,000) and Option ($100,000).
  - Must meet minimum percentage of work; 40% of the work is performed by the proposing small business concern, and a minimum of 30% of the work is performed by the single research institution.
- **Company Commercialization Report (Volume 4).** The CCR (Volume 4) will not be evaluated by the Navy nor will it be considered in the Navy’s award decision. However, all proposing small business concerns must refer to the DoD SBIR/STTR Program BAA to ensure compliance with DSIP Volume 4 requirements.

- **Supporting Documents (Volume 5).** Supporting Documents (Volume 5) will not be considered in the selection process and will only undergo a compliance review to ensure the proposing small business concern 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 proposing small business concerns 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. Proposing small business concerns 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 $1,800,000 or lower limit specified by the SYSCOM). As with Phase I, the amount proposed for TABA cannot include any profit/fee by the proposing small business concern and must be inclusive of all applicable indirect costs. TABA cannot be used in the calculation of general and administrative expenses (G&A) for the SBIR proposing small business concern. 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 small business concern receiving TABA will be required to submit a report detailing the results and benefits of the service received. This TABA report will be due at the time of submission of the final report.

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 (to include the purpose and objective of the assistance)
- Total TABA provider(s) cost, number of hours, and labor rates (average/blended rate is acceptable)

TABA must <u>NOT</u>:

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

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 5) – a detailed request for TABA (as specified above) specifically identified as “TABA” in the section titled Additional Cost Information when using the DON Supporting Documents template.
- 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 “TABA” in the section titled Additional Cost Information when using the DON Supporting Documents template.

Proposed values for TABA must <u>NOT</u> 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 proposing small business concern requests and is awarded TABA in a Phase II contract, the proposing small business concern 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 participate in the virtual DON STP Kickoff during the first or second year of the Phase II contract. While there are no travel costs associated with this virtual event, Phase II awardees should budget time of up to a full day to participate. STP information can be obtained at: https://navystp.com. Phase II awardees will be contacted separately regarding this program.

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 proposing small business concern 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 small business concern 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 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.

Partnering Research Institutions. The Naval Academy, the Naval Postgraduate School, and other military academies are Government organizations but qualify as partnering research institutions. However, DON laboratories DO NOT qualify as research partners. DON laboratories may be proposed only IN ADDITION TO the partnering research institution.

System for Award Management (SAM). It is strongly encouraged that proposing small business concerns 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, proposing small business concerns 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 small business concern 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 proposing small business concerns 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.nre.navy.mil/work-with-us/how-to-apply/compliance-and-protections/research-protections. 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 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 proposal of the proposing small business concern 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. Interested parties have the right to protest in accordance with the procedures in FAR Subpart 33.1.

Pre-award agency protests related to the terms of the BAA must be served to: osd.ncr.ousd-r-e.mbx.SBIR-STTR-Protest@mail.mil. A copy of a pre-award Government Accountability Office (GAO) protest must also be filed with the aforementioned email address within one day of filing with the GAO.

Protests related to a selection or award decision should be filed with the appropriate Contracting Officer for an Agency Level Protest or with the GAO. Contracting Officer contact information for specific DON Topics may be obtained from the DON SYSCOM Program Managers listed in Table 2 above. For protests filed with the GAO, a copy of the protest must be submitted to the appropriate DON SYSCOM Program Manager and the appropriate Contracting Officer within one day of filing with the GAO.

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 the proposing small business concern, 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 small business concern 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 $1,800,000 (unless non-SBIR/STTR funding is being added). Individual SYSCOMs may award amounts, including Base and all Options, of less than $1,800,000 based on available funding. The structure of the Phase II proposal/award, including maximum amounts as well as breakdown between Base and Option amounts will be provided to all Phase I awardees either in their Phase I award or a minimum of 30 days prior to the due date for submission of their Initial Phase II proposal.

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 small business concern'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 small business concerns (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 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.

Navy STTR 23.A Topic Index

N23A-T001	DIGITAL ENGINEERING - Toolkit to Produce Common Adaptive Mesh for Virtual Reality-based Multidisciplinary Interactive Design of Naval Aircraft
N23A-T002	DIGITAL ENGINEERING - Integration of Fiber Optics Systems Design, Supportability, and Maintainability
N23A-T003	DIGITAL ENGINEERING - Improved Physics Modeling for Sand Particulate Tracking and Deposition in Gas Turbine Engines
N23A-T004	DIGITAL ENGINEERING - Digital Twin-based Machine Control for Adaptive Additive Manufacturing Processing of Metallic Aerospace Components
N23A-T005	Sensor System for Time-Resolved Temperature Measurements in High-Temperature/High-Velocity Exhaust Plumes
N23A-T006	Microwave Curing Process Modeling for Continuous Carbon Fiber Reinforced Thermoset Composites
N23A-T007	Ultra-Compact, Lightweight MWIR Zoom Imaging Optics Based on Flat Lens Technology
N23A-T008	Ultra-fast Full-Wave Photonic Simulation and Optimization
N23A-T009	DIGITAL ENGINEERING - Generalizable Tactical Software AI/ML-informed Debloating
N23A-T010	DIGITAL ENGINEERING - Sonar Dome Anti-Fouling Tracking and Prediction Tool
N23A-T011	Innovative Optics for Wide Field of View Infrared Sensors
N23A-T012	Atmospheric Aerosol Model and Data Collection Over the Marine Boundary Layer for Imaging/Radiofrequency (RF) and Laser Beam Propagation
N23A-T013	Unmanned Underwater Vehicle (UUV) Sensor Data Transformation Tool
N23A-T014	DIGITAL ENGINEERING - Automated Knowledge Base Extraction and Student Assessment
N23A-T015	Scalable Net-Zero JP-10 Production from Non-Fossil Fuel Resources
N23A-T016	Lightweight Turbogenerator for Vertical Take-off and Landing Unmanned Aerial Systems- in Marine Environments
N23A-T017	Coherent Sensing Approaches for Dynamic Spectrum Allocation
N23A-T018	Reliable Hydroxyl-Terminated PolyButadiene for Rocket Motors

N23A-T019	Electrochemical Machining of Turbine Engine Components
N23A-T020	Scalable Production of Carbon-Based Composites from Sequestered Environmental Carbon
N23A-T021	Autonomous, Long-Duration, Directional Ambient Sound Sensor
N23A-T022	Lightweight Mirrors for Microsatellites and Small Satellites
N23A-T023	Integrated Optical Imaging of the Environment on Underwater Autonomous Vehicles
N23A-T024	Compact Condensers Enabled by Additive Manufacturing
N23A-T025	Cloud Nowcasting Data/Model Fusion
N23A-T026	Development of Finite-Rate Ablation Toolset for Hypersonic Vehicles
N23A-T027	Digital Sidekick for Submarine Watchstander Augmentation
N23A-T028	Broadband, High Power, Low Loss N-polar GaN Radio Frequency (RF) Switches
N23A-T029	Non-Intrusive Aerodynamic State Sensing for Hypersonic Flight Control

N23A-T001 TITLE: DIGITAL ENGINEERING - Toolkit to Produce Common Adaptive Mesh for Virtual Reality-based Multidisciplinary Interactive Design of Naval Aircraft

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Computing and Software

OBJECTIVE: Develop an innovative tool that can autonomously generate a common mesh from Computer-Aided Design (CAD) geometry with adaptive global and local refinement capabilities for coupled aero-thermal-structural analysis and optimization to enable Virtual Reality (VR)-based real-time interactive designs.

DESCRIPTION: Digital engineering for aircraft development can be accelerated by multidisciplinary design, analysis, and optimization (MDAO). The core component of MDAO for hypersonic aircraft is the multi-physics simulations involving the interplay between high-speed aerodynamics, structural dynamics, and thermodynamics. Aero-structure-thermal simulations could dramatically reduce the ground-based and in-flight tests as more capable high-performance computing (HPC) hardware can afford higher resolutions of geometrical and physical complexities — i.e., if a 10 cm accuracy in the 1980s for an aircraft was the standard, 1 mm for the geometry and 1 μm in the boundary layer resolution is now commonplace.

However, these increasing geometrical accuracy requirements and physical complexities pose grand challenges in mesh generation [Refs 1–2]. According to the NASA CFD Vision 2030 [Ref 3], mesh generation and adaptivity persist as significant bottlenecks in computational fluid dynamics (CFD) workflow. On the one hand, autonomous and geometry-aware mesh generation techniques are still lacking. Generating high-quality meshes by existing approaches [Refs 4–7] from complex CAD models of aircraft still involves time-consuming human intervention, and the resulting meshes do not retain the parameterization of the geometry. The geometric discrepancy can lead to significant errors in the prediction of critical physics, such as shock-boundary layer interaction and fatigue/damage in structures. On the other hand, mesh adaption can substantially save CPU time, memory requirement, and storage space. However, controlling the error and generating the optimal mesh for a given accuracy is challenging [Ref 9]. Automatic mesh adaption with local and global refinements in critical regions without prior knowledge of the problem is also a difficult task [Ref 1]. Resolving these challenges, which have been hampering automatic and adaptive mesh generation for complex geometries, will dramatically facilitate simulation-based aircraft design and optimization and have a far-reaching impact on Navy's missions. An adaptive, common mesh generation tool is needed to facilitate the MDAO to accelerate aircraft development. The effectiveness of the tool is measured by reducing the time, and therefore cost, required to develop the multi-physics meshes. The tool should enable autonomously-generated geometry-aware mesh generation and adaption, which can be integrated into the simulation tools of aircrafts involving CFD (e.g., hypersonic flows), fluid-structure interaction (FSI), fatigue/damage, and thermodynamics. The developed tool should be flexible, i.e., able to handle various air vehicle geometries. The tool should allow automatic mesh adaption with no or minimal dependence on prior knowledge in multi-physics simulations for critical quantities at critical locations, such as shock and turbulence in the fluid domain, as well as mechanical and thermal variables in the structural domain. The mesh generation and adaption tool should have quantification metrics, control strategies, and error estimates to assist the user in obtaining reliable simulation results with the first mesh. It should also address both body-fitted meshes and nonbody-fitted meshes, as the latter meshes are essential for the feasibility, as well as efficiency of MDAO problems where the geometry undergoes large shape and/or topological changes, and the multidisciplinary simulations involve large structural displacements, rotations and/or deformations [Ref 10]. The toolkit should enhance the user's experience with virtual reality by improving visual understanding of the mesh with respect to the geometry through the interaction of the various physics.

PHASE I: Demonstrate the capability of the mesh generation tool and its integration with a prototype simulation toolkit design. Illustrate a workflow for a multidisciplinary analysis along with the local-global coupling for a representative aircraft structural component subjected to a given operational profile. Demonstrate the effectiveness and cost saving in design iteration in comparison with a conventional approach. Show the autonomous capability of meshing complex CAD models and adaption upon mesh generation, capturing critical features such as shocks or stress concentrations. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate, and validate the prototype design from Phase I. Fully integrate the mesh generation technique with multi-physics simulation tools of aero-structure-thermal analysis for aircraft development. Quality metrics for the fully functional software product should include the automatic meshing adaptivity to capture the local physics and meshing transformation between different physical problem descriptions. Incorporate virtual reality to enhance the user’s understanding of the mesh and how it relates to the geometry. The virtual reality should also enhance understanding of the solution and the interactions of various physics. Show the applicability of the tool using commercially available or open literature CAD data for the original design and specifications. Demonstrate its advantages in terms of cost, accuracy, and robustness in the context of MDAO to reach an optimized design under fluid-thermal-mechanical loading.

PHASE III DUAL USE APPLICATIONS: Demonstrate capability to model a flight test event with inclusion of fluid-thermal-mechanical loading and show it provides risk reduction for the test event.
The use of multidisciplinary simulations is becoming more common for commercial products. Beyond the natural need of the commercial aerospace industry, many other industries are interested in multi-physics simulations. Civil engineering needs to consider fluid-structures interactions. Fluid-thermal interactions are critical for electronics. The automotive industry is interested in fluid-thermal-structural analysis, with rapid turnaround. These industries will benefit from more capable and quicker multidisciplinary mesh generation.

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KEYWORDS: Mesh Generation; Adaptive Meshing; Global-local modeling; Multidisciplinary Analysis; multi-disciplinary design, analysis, and optimization; virtual reality

N23A-T002 TITLE: DIGITAL ENGINEERING - Integration of Fiber Optics Systems Design, Supportability, and Maintainability

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics; Integrated Network Systems-of-Systems

OBJECTIVE: Develop modeling approach for designing, maintaining, and supporting air and sea platform digital and analog fiber optic communications technology.

DESCRIPTION: The use of optical fiber on air, surface ship, and undersea platforms is pervasive, and is an enabling technology. Current military electronics, electro-optic, communications, radar, and electronic warfare systems require ever-increasing bandwidths, while simultaneously demanding reductions in space, weight, and power (SWaP). The effectiveness of these systems hinges on optical communication components that realize sufficient link budget, dynamic range, and compatibility with military surface ship, undersea platform, and aircraft maintenance environments [Refs 1-5]. Future digital and analog/radio frequency (RF) signal transmission rates and frequencies have increased to the point where fiber optics is the only medium with the capacity and low loss for maintaining communications signal integrity. Maintainability and supportability are well-known operational availability drivers for fiber optics technology deployment on military platforms [Ref 6]. Key systems engineering design considerations include architecture (openness, modularity, scalability, and upgradeability), reliability, maintainability, and supportability. Supportability infrastructure is difficult to add on after the design is established, and therefore should be included in the systems engineering design process.

Key fiber optics systems engineering design considerations include architecture, reliability, maintainability, and supportability. Integrating the disparate interfaces associated with digital and analog/RF fiber optic systems, and a model-based engineering approach, requires significant digital engineering research and innovation. Although the Navy has complete knowledge of the required connections and interfaces for digital and analog/RF fiber optics, there is no model-based approach to selecting components (connectors, cable, termini, transmitters, receivers), support equipment (maintenance sets), training, and the required supportability and maintainability concepts. MIL-HDBK-217 requires modernization for fiber optics reliability engineering [Ref 7]. This digital engineering research effort should develop models that include all of the platform components, support equipment, associated fleet maintainer training, reliability data, and digital and analog/RF fiber optic system design engineering principles. Digital engineering research should capture approaches to minimize the number and diversity of parts and interfaces, and be applicable to aircraft, surface ship, and undersea platform specific model-based system-engineering models. Digital engineering research is also required to understand how to best utilize the existing CAMEO Systems Modeler tool [Ref 8] and Systems Modeling Language (SysML) [Ref 9] for ship and aircraft fiber optics hardware integration, relevant use cases, use of existing standards, digital and analog/RF link design principles, and use of existing and emerging components.

Fiber optics supportability cuts across reliability, maintainability, and the supply chain to facilitate detection, isolation, and timely repair/replacement of system anomalies. Typical supportability features include prognostics, diagnostics, skill levels, support equipment footprint, training, maintenance data collection, compatibility, packaging and handling, and other factors that contribute to an optimum environment for sustaining a fiber optic system. The ability to sustain the operation of a fiber optic system on a surface ship, undersea platform or aircraft, is established by the inherent supportability of the system and the processes used to sustain the functions and capabilities of the system in the context of the end user. The focus of sustainment planning is to influence the inherent supportability of the system and to plan the sustainment capabilities and processes used to sustain system operations. Sustainment influence requires an understanding of the system missions and mission profiles and to provide rationale for functional and performance priorities. Understanding the rationale paves the way for decisions about necessary tradeoffs between system performance, with impact on the cost effectiveness of system operation, maintenance, and logistics support. There is no single list of sustainment considerations or a specific way of grouping system operation, maintenance, and logistics support, as they are highly inter-related. They include compatibility, transportability, the actual maintenance environment, diagnostics and prognostics (including real-time maintenance data collection and built-in test), and corrosion protection and mitigation.

Fiber optics maintainability considerations encompass modularity, interoperability, physical accessibility, training, testing, and human systems integration. Maintainability generally requires balancing the maintenance requirement over the life cycle with minimal user workload. The emphasis on maintainability is to reduce the maintenance burden and supply chain by reducing time, personnel, tools, test equipment, training, facilities, and cost to maintain the system. Maintainability engineering includes the activities, methods, and practice to design minimal system maintenance requirements and associated costs for preventative and corrective maintenance, as well as servicing and calibration activities. Maintainability should be a designed-in capability and not an add-on option, because good maintenance procedures cannot overcome poor system and equipment maintainability design. The primary objective is to reduce the time and complexity for a properly trained maintainer to detect, isolate and repair a failure.

PHASE I: Collect research data on fiber optic components, link-loss power budget methodologies, system design concepts, maintenance concepts, support equipment concepts, and overall maintainability and supportability. Using SysML, create handoff between reliability, maintainability, and supportability within the bounds of the military platform fiber optic systems engineering process. Identify key risk areas for tracing lower level fiber optic system designs to higher level supportability and maintainability considerations to realize desired life cycle performance, and mitigate these risks using digital engineering research concepts and modeling tools. Demonstrate operational suitability trade-offs of model-based system engineering approaches to fiber optic system design and support. The Phase I effort shall include plans to be developed under Phase II.

PHASE II: Develop digital engineering-based prototype software to enable modeling of fiber optics integration in the context of supportability and maintainability. Optimize the model designs using representative cases from ships and aircraft. Build and test support equipment prototypes based on results from the models. Determine the efficacy of the entire support concept. Deliver the SysML model and digital engineering software.

PHASE III DUAL USE APPLICATIONS: Finalize the application. Verify and validate the application in model-based systems engineering environments that are applicable to aerospace, surface ship, and undersea platforms. Transition to applicable naval platforms.

Commercial sector telecommunication systems, fiber optic networks, and data centers could benefit from the development of this application.

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KEYWORDS: Fiber optics; system design; supportability; maintainability; model-based systems engineering; digital engineering

N23A-T003 TITLE: DIGITAL ENGINEERING - Improved Physics Modeling for Sand Particulate Tracking and Deposition in Gas Turbine Engines

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Computing and Software
OBJECTIVE: Improve time-varying modeling and simulation capabilities to couple representative reactive sand particulates with modern propulsion systems, including inlet and turbomachinery.

DESCRIPTION: Naval aircraft powered by gas turbine engines experience safety, performance, and reliability concerns when operating in degraded visual environments with significant concentrations of reactive dust and sand. Sand particulates—including sand, salt, dust, and volcanic ash that aren't filtered or separated by an existing inlet or engine mounted filtration system—are ingested into the gas turbine engine.

Improved modeling and simulation tools will help better characterize the sand particulate impact on turbomachinery within aircraft propulsion systems. Current systems can have safety impacts when operating in sand and dust related to sand deposition within the turbine leading to engine surge and potential loss of aircraft. Engine reliability is heavily impacted by sand ingestion, which can lead to faster engine deterioration with significant life cycle cost. Improved understanding of the impacts and design changes using modeling tools would have a positive impact on capability, performance, and cost.

Ingested particles can degrade compressor performance via surface erosion, deform leading and trailing edges of blade airfoils, and open rotor tip-clearances [Ref 4]. Sand particulates that make it through to the combustor are elevated to high temperatures and can deposit on turbine airfoil surfaces—shrinking throat clearances—or deposit on turbine shroud and degrade turbine tip clearances. Sand particulates can also enter cooling passages and create deposits that block cooling flows resulting in exceedance of airfoil material temperature limits. This can affect both military and commercial aircraft and rotorcraft. Sand ingestion and deposition can be further impacted by relevant sand properties (geology, chemical composition, size distribution, shape, concentration) [Ref 3].

Airflow restrictions can occur rapidly on wing, and result in sand related operability impacts that can cause safety issues with undesired engine surge and stall events. Additionally, performance loss from significant turbine airfoil damage typically cannot be recovered entirely via engine wash or other maintenance procedures. This can lead to more frequent engine replacements and an overall reliability concern for the propulsion system. Complex propulsion systems of interest include inlets, inertial separators, hot and cold rotating turbomachinery with and without secondary cooling air flow, as well as the coupling of multiple of these components.

Current state-of-the-art modeling and simulation tools typically couple steady-state Reynold's averaged navier stokes (RANS) computational fluid dynamics (CFD) solvers to a discrete particle tracking tool. This method has several disadvantages, including inaccurate inclusion or modeling of turbulent particle dispersion, limited particle-to-particle collisions and interaction, simplified particle shapes that affect drag estimates and wall-impacts/rebounds, one-way coupled particles that don't affect gas aerodynamics, and deposition predictions that use frozen geometry shapes and wall properties that can't change in time as the deposit size increases. Unsteady Large Eddy Simulation (LES) typically include more rich physics-based models that incorporate more of the above RANS deficiencies; however, they can also be computationally expensive and too long to impact design iterations or active acquisition programs. Additionally, the vast amount of data available from a resolved simulation with millions of particulates is frequently difficult to post-process and analyze efficiently. Efficient algorithms and post-processing methodologies to cumulatively understand time-accurate statistical measures of the ingested sand particulates are required. Modeling and simulation tools need to be improved to be able to accurately predict time-varying particle trajectories, wall-impacts, surface erosion, and surface deposition within inlet systems and engine turbomachinery [Ref 5]. Improvements to accuracy and confidence of modeling methodologies, as well as significant improvements to computational cost and efficiency to be able to impact a typical design cycle, are desired. The proposed approach's accuracy and applicability to relevant, complex propulsion systems should be demonstrated via comparisons against available (published), acquired experimental data, or government-provided test data.

A focus on robust, parallel, highly efficient software improvements that can be utilized for complex geometries (such as inertial separators and rotating turbomachinery with secondary and cooling flows) with relevant sand particle constituents, size distributions, and cloud concentrations [Ref 1], is required. Although not required, it is highly recommended that the proposer work in coordination with the original equipment manufacturer (OEM) to ensure proper design and to facilitate transition of the final technology.

PHASE I: Demonstrate understanding of relevant sand properties, including those of reactive sand and dust (geology, chemical composition, size distribution, shape, concentration). Demonstrate and validate the use of a commercially available CFD solver that has been coupled to incorporate sand particulates. Validate selected aerodynamic software on relevant turbomachinery geometry. Define the approach to be used in Phase II for improved physics modeling and robust, efficient solver development that can be applied to complex propulsion systems. Provide risk mitigation information. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and demonstrate the prototype improved sand and dust modeling capability. Show efficient integration of reactive capability with existing, commercially available CFD software. Evaluate and report on the tool improvements impact on accuracy against available (published), acquired experimental data, or government-provided test data. Provide clear documentation of the theory, applied models and methods, assumptions, limitations, and instructions for use of the coupled aerodynamic and sand predictive tool. Demonstrate computational efficiency and robustness on DoD High Performance Computing assets.

PHASE III DUAL USE APPLICATIONS: Transition developed tool and capability to government for implementation on fleet aircraft. Modify tools based on feedback from use within a DoD acquisition program. Support the application of advanced, mature, robust tools on aircraft engine and inlet analysis and redesign.

Commercial aircraft engines experience sand and dust deterioration over long-time exposures. This can also impact performance and reliability of commercial engines. Improved modeling and simulation for better understanding and design methodologies will also impact aircraft engines for rotary- and fixed-wing commercial aircraft.

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KEYWORDS: Gas Turbine Engines; Degraded Visual Environments; Sand and Dust Ingestion; Computational-Fluid Dynamics; High Performance Computing; Sand Deposition

N23A-T004 TITLE: DIGITAL ENGINEERING - Digital Twin-based Machine Control for Adaptive Additive Manufacturing Processing of Metallic Aerospace Components

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy

OBJECTIVE: Develop a digital twin (DT)-based system that can autonomously tailor local microstructure, heal defects, and minimize residual stresses and surface roughness in near real-time to assure repeatable, reliable, and optimal fatigue performance for additive manufactured (AM) metallic aerospace components.

DESCRIPTION: Additive manufacturing (AM) has attained significant popularity in research and application fields such as aerospace, automobile, maritime, biomedical, and other industrial sectors. AM processes are capable of depositing near-net-shape complex geometries; but major drawbacks of the AM materials remain, including anisotropy, surface irregularities, residual stresses, and defects (such as porosity, microcracks, inclusions, dislocations, etc.). These drawbacks significantly influence the static and dynamic mechanical properties of a material. As a result, the AM parts still lack quality consistency and repeatability. While post-processing such as Hot Isotropic Pressing (HIP) could enhance performance for some alloys, it could lead to additional cost and production time.

The various defects in AM processing can arise due to many causes, and significant attention has been given to different strategies to ameliorate these defects. Two significant types of defects observed from AM processing are lack-of-fusion (LOF) defects and gas porosity. LOF occurs when an insufficient amount of energy is applied to melt a specific location of a powderbed. This is directly influenced by site-specific processing parameters, such as laser power, hatch spacing, and scan speed. A rescanning strategy in the region with the LOF may eliminate the LOF defects. Gas porosity is often spherical due to gas trapped in the raw metal powder particles or trapped inert gas during the AM processing. It has been shown that gas porosity can be minimized with increasing scan speed and appropriate power level. Another challenge that causes build failures and poor part quality is large residual stresses due to the high cooling rates in AM processing. However, recent research has found that rescanning the top layer reduces residual stresses near that surface. In order to enable in-situ controlling the quality of the build, a monitoring and control system is necessary.

There are several in-situ monitoring methods that have been demonstrated. For example, in order to capture the porosity, a high-speed camera and a photodiode were used to measure the dimensions of the melt pool condition and the mean emitted radiation. A two-color pyrometer was used to relate the consolidation phenomena with the surface temperature and to understand the solidification process of the molten powder. However, the collected data could be enormous (~0.5 Terabytes per build) requiring a large amount of storage and fast computational algorithms. Furthermore, the level of accuracy to detect and classify defects/anomalies still needs significant improvement, especially minimizing false positives and negatives.

Once the undesirable state of the deposit is monitored and sensed, near real-time healing and tailoring of the deposit are needed. A close-loop feedback laser system, such as a laser with shaped beam profiles, may be used for in-situ treatment of the deposit, as well as preventing material spattering and defects. For example, it was reported that equiaxed grains occupied a larger area fraction, and texture was reduced in parts built using an elliptical beam, compared to those built using a Gaussian beam. Laser power and wavelength control could also tailor the cooling rate to prevent cracking and improve the mechanical properties of the part. The use of ring distributed power in welding can result in a decrease of laser penetration depth, along with huge spatter reduction observed on the deposited bead and surrounding area. However, a near real-time close-loop feedback system also requires robust reduced-order/surrogate modeling coupled with Artificial Intelligence (AI)/Machine Learning (ML) that link powders, process parameters, microstructure, and site-specific properties at the component level, including the effects of build orientation, laser-material interaction, and specific part geometry. These are the key elements of a DT-based system.

The Navy requires an integrated DT-based system that can provide near real-time machine control for fully autonomous adaptive AM processing of metallic aerospace components. The system should be able to: (a) locally re-scan and re-melt; (b) autonomously adjust and control deposited energy density including laser power/intensity, spot size, and beam shape/profile, (de)focusing, scanning speed and pattern, hatch spacing, layer thickness, and interlayer delay time; and (c) build time of a complete part should not exceed by more than 20% compared to the traditional fixed parameter pre-set method. It is envisioned that such an in-situ tailoring/healing system will not only significantly improve the fatigue life performance comparable to wrought alloys, but also assure the repeatability and reliability of AM structural parts.

PHASE I: Demonstrate feasibility of a feedback control concept that integrates with a beam shaping laser system, sensors, ML-enabled monitoring and control methodologies, and reduced-order modeling (ROM) for Laser Powder Bed Fusion (LPBF) system. Demonstrate the feasibility of healing and tailoring the AM deposit. A detailed plan should be laid out to perform the validation of the effectiveness of the concept with implementation for a metallic alloy such as AlSi10Mg aluminum. The concept should have the potential to be developed into a full-scale, near real-time, in-situ monitoring and control system of an AM process to improve fatigue properties in Phase II. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate, and validate the prototype system developed in Phase I. Fully develop and validate the ML-enabled monitoring and control system with reduced-order modeling for a laser-based AM process to efficiently and robustly heal and tailor the AM deposited material properties, based on the optimized AM process parameters for additional selected materials, such as Ti6Al4V, SS316L, and aluminum alloys. Demonstrate its capability of manufacturing aircraft components with complex geometry and tailored performance.

PHASE III DUAL USE APPLICATIONS: Fully develop the advanced monitoring and control system coupled with reduced order models for various laser-based AM processes to fabricate naval aircraft components that can be integrated into the fleet. Conduct final component-level testing to achieve the geometry and material property of AM components meeting the Navy’s needs.

The monitoring and control system will be directly applicable to a wide range of AM process methods and machines due to the high amount of usage of AM parts in the commercial aerospace and medical industries. The oil and gas, automotive, and shipping industries could also benefit from this developed technology.

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KEYWORDS: Additive Manufacturing; Digital Twin; In-situ Monitoring; Closed-Loop Feedback Control; Artificial Intelligence/Machine Learning; Reduced-Order Modeling

N23A-T005 TITLE: Sensor System for Time-Resolved Temperature Measurements in High-Temperature/High-Velocity Exhaust Plumes

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Materials

OBJECTIVE: Develop a time-resolved sensor system for measuring gas dynamic and compositional characteristics of high-temperature/high-velocity engine exhaust plumes.

DESCRIPTION: Time-resolved measurements in high-temperature and high-velocity exhaust plumes are necessary to better understand transient phenomena including startup/shut down, combustion instabilities, and flow nonuniformity. Measurement parameters of interest in exhaust plumes include temperature, pressure, velocity, combustion efficiency, and gas composition.

High-temperature, high-velocity exhaust plumes present a uniquely challenging measurement environment. Wetted sensors, such as thermocouples and pressure transducers, degrade rapidly in reactive, particle-laden, high-temperature, high-velocity plume flows, emphasizing a need for noninvasive measurement approaches. Similarly, noninvasive optical techniques are hampered by low-transmission, large-density gradients, and high-thermal, spontaneous emission in hot, fast, particle-laden flows. An innovative sensor system is desired for measurements in high-temperature and high-velocity exhaust plumes. Extending existing measurement technologies to full-scale engines requires improved strategies in sensor survivability, overcoming poor signal-to-noise ratio, and the extreme acoustic and vibratory environment in close proximity to the exhaust plume.

Key sensor system parameters should include, but not be limited to the following:

1. Measuring temperature is of primary interest. Additional measurement parameters of interest include pressure, velocity, combustion efficiency, and gas composition. Desired speciation of composition measurements include unburned fuel components, intermediate fuel-cracking products, and final products (CO, CO2, H2O, NO, NO2).
2. Temperature measurement accuracy must be better than +/- 5%.
3. Sensor must provide, spatially-resolved point or line-averaged measurements to a resolution of at least 1 mm or smaller. Two-dimensional maps of measurement parameters are also of interest.
4. Minimum sensor bandwidth must exceed 1 kHz. Increased bandwidth up to 100 kHz is preferred.
5. The operational envelope for the sensor must span temperatures from 500–3,000 K (227–2727 °C).
6. Optical sensors are of interest to provide noninvasive measurements that do not perturb plume characteristics. Optical sensors must be capable of performing measurements in particle-laden, highly emissive flows.
7. Sensor lifetime for high-temperature, high-velocity exhaust plume measurements must exceed 1,000 hr.

PHASE I: Develop a concept and determine the feasibility of a sensor system for time-resolved measurements in high-temperature, high-velocity exhaust plumes with the ideal goal of providing greater than 1 kHz measurement bandwidth. Ensure that the concept sensor provides point- or line-averaged measurements of temperature over the range of 500 to 3,000 K (227–2727 °C).

Additional measurement parameters—including pressure, velocity, combustion efficiency, and composition—are of interest, but not required, in Phase I. Noninvasive optical measurement approaches are desirable, but must be able to operate in flows with high-particulate loads (low transmission) and high emission. Phase I should include (a) benchtop testing and validation of sensor concept and accuracy in controlled high-temperature gas environment, (b) designs for construction of field-deployable sensor prototype, and (c) detailed prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate, and validate a prototype sensor. Improve upon the performance, reliability, and usability of the sensor. Perform field demonstrations, which will guide sensor improvements. Desired improvements include (a) measurement bandwidth in excess of 10 kHz, (b) temperature measurement accuracy better than +/- 5%, (c) measurements at multiple locations within a plume, including close proximity to the nozzle exhaust, and (d) increased capability to handle all relevant engine operating conditions. Include the extension of the sensor prototype to include additional measurement parameters such as pressure, velocity, combustion efficiency, and/or composition. Include (a) revision of the sensor design to improve performance, reliability, and usability; (b) successful demonstration of temperature measurements using the second-generation prototype in high-temperature/velocity exhaust plume; (c) successful demonstration of additional measurement parameters using the second-generation prototype in high-temperature, high-velocity exhaust plume; and (d) delivery and initial testing of the sensor prototype.

PHASE III DUAL USE APPLICATIONS: Complete final testing and transition the technology for Navy use. Accurate time-resolved measurements of aircraft engine, rocket, and other plumes could steer development of commercial propulsion systems and modeling tools used in their development.

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KEYWORDS: High Temperature Sensor; Temperature Measurement; Time-Resolved; Plume Measurements; Combustion Measurements; Gas Composition Measurement

N23A-T006 TITLE: Microwave Curing Process Modeling for Continuous Carbon Fiber Reinforced Thermoset Composites

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Computing and Software; Advanced Materials

OBJECTIVE: Develop simulation models and visualization tools for microwave curing process of carbon fiber reinforced composites, and demonstrate the feasibility to manufacture high quality carbon fiber reinforced composites using microwave radiation.

DESCRIPTION: Autoclaves are widely utilized to process and manufacture high-performance aircraft composite materials. This conventional method provides laminate consolidation by application of elevated pressures and temperatures; however, the high costs and extensive process times associated with this technique have generated an interest in the implementation of out of autoclave curing methods. Microwave curing is gaining increasing attention as an alternative tool for composite industrialization, due to its potential for reduced cure times, low energy consumption, and mass production.

Microwave systems heat materials via electromagnetic field interaction. Electromagnetic fields are transferred to the material, and heat is generated through polarization. Microwave curing has been used for glass fiber composite processing, but there are significant challenges associated with microwave curing of carbon fiber composites. Efficient heating is difficult due to high dielectric loss and low depth of penetration associated with carbon fibers. Another major challenge is related to arcing of carbon fibers, which can result in very high-localized hot spots that damage the surrounding material. Laminate quality is highly dependent on the uniformity of the electromagnetic field in the material. The anisotropic dielectric properties of composite constituents disrupts the intended homogeneous volumetric cure, resulting in non-uniform heating. This heating behavior requires further investigation; highlighting the need for a tool that can model this phenomenon.

This STTR topic seeks to develop a multi-physics based model that simulates and optimizes the microwave curing process of thick fiber reinforced composites (up to 10 mm). The model should account for the interaction of electromagnetic, thermal, and chemical mechanisms induced during the curing process. The tool will be used to model aerospace-grade thermoset composite materials (such as IM7/8552) of varying lay-up thicknesses and fiber orientations, to predict curing behavior and material properties. The model predictions for microwave cured fiber reinforced composites will be validated by qualitative (such as porosity, defects, etc.), mechanical (such as tension, flexure, impact, etc.) and chemical (such as differential scanning calorimetry, dynamic mechanical analysis, etc.) coupon testing. The implementation of a microwave curing process would result in reduced cure times and reduced energy consumptions. The modeling tool would aid in the reduction of test runs required for composite part production. It would also give companies greater production scheduling freedom through process modeling of components. This would make production more adaptive and save scheduling time and costs.

PHASE I: Develop a modeling methodology based on the proposed concept of a multi-physics tool that can simulate and optimize the microwave curing process of fiber reinforced composite materials. Demonstrate feasibility of the methodology and investigate the effects of the microwave curing conditions, such as power, duration, composite orientation, composite thickness, etc., via simulations, that account for electromagnetic, thermal, and chemical mechanisms on the mechanical properties of the cured composite. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop the proposed multi-physics tool to address microwave manufacturing of fiber reinforced composites of thicknesses up to 10 mm. Demonstrate and validate the tool by comparing simulation predictions to the results of various qualitative, mechanical, and chemical tests of microwaved and autoclaved cured fiber reinforced composite coupons.

PHASE III DUAL USE APPLICATIONS: Enhance and demonstrate this tool with difficult to process parts, associated with autoclave curing, and with different material systems. Coordinate with the prime and sub-contractors producing composite parts to facilitate the transition and utilization of this tool.
The product outcome of this topic has extensive applications for companies producing fiber- reinforced composite parts, in particular companies that utilize an autoclave process. This topic desires to provide a modeling tool to optimize the alternative microwave curing process for the production of quality parts at a lower cost (50% reduction) and quicker turnaround times (40% reduction).

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KEYWORDS: Microwave curing; Manufacturing process; Physics-based modeling; Carbon fiber thermoset composites; Process optimization; Mechanical testing

N23A-T007 TITLE: Ultra-Compact, Lightweight MWIR Zoom Imaging Optics Based on Flat Lens Technology

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Integrated Sensing and Cyber; Advanced Materials

OBJECTIVE: Develop ultra-compact, lightweight Mid-wave infrared (MWIR) zoom imaging optics based on flat lens technology and with 7 times improvement in SWaP.

DESCRIPTION: MWIR imaging systems are essential to intelligence, surveillance, and reconnaissance (ISR) missions. Conventional IR optics are thick, heavy, costly, and often require bulky mechanical mounting system to keep their multiple optical elements stable and well-aligned. Current systems weigh 400 g or more, often necessitating heavy-duty gimbals for aiming. Heavy optics require tens of minutes to reach thermal equilibrium during takeoff and landing of air platforms such as unmanned aircraft systems (UASs), limiting ISR operations.

Flat lens technologies have the potential to provide extremely compact and lightweight imaging capability in the MWIR, including reduced costs and added functionality such as zoom or variable focus [Refs 1 & 2]. Microfabricated flat lens optics can be only 1 mm thick or less, reducing overall lens system length and supporting more compact imaging systems. Their extremely low mass allows them to reach thermal equilibrium in less than one minute in typical airborne scenarios. Two promising flat lens technologies are metasurface optics (or meta-optics) [Refs 3–5], and multilevel diffractive lenses (MLD) [Ref 6]. Both have challenges related to scalable fabrication and with chromatic aberration for broadband applications. The MLD approach has challenges associated with large numerical apertures (small f-numbers) and high throughput, especially for oblique angles of incidence, which gives rise to significant vignetting, that is, reduction of the image's brightness toward the sensor periphery compared to center. Meta-optics can achieve extremely low-aberration imaging, often reducing the number of optical elements required. As the design space and device function complexity of flat lenses scales up, limitations of the conventional human-driven forward design of meta-optics have necessitated a breakthrough in design philosophy. Recent work using inverse design with appropriate artificial intelligence (AI) tools positions this method to transform meta-optics design [Refs 7–9]. The inverse design approach explores the physics of nanophotonics using advanced mathematical tools, iterating until an optimal solution is achieved. Inverse design has significant advantages over conventional forward design: it does not need a priori knowledge of physics; it can be used for complex designs that have no analytical solution; and it can automatically balance the trade-offs among multiple device functions given the design constraints while minimizing crosstalk. Design robustness can also be considered using the inverse design techniques.

The development of a novel lightweight, low-aberration flat lens-based MWIR zoom optics must achieve certain minimum specifications in performance and size, weight, and power (SWaP) to accelerate its adoption for next-generation ISR missions. For example, the aperture size and f/# must be large enough to be useful for low-light imaging. For this effort, the target specifications include, but are not limited to, the follows:

(a) total weight, including housing, mount, and motorized control: 100 g or less
(b) axial length of lens elements: 2 cm or less (i.e., > 7 times improvement over conventional zoom lens),
(c) focal length range: f/2 for wide field of view (FoV), variable up to f/8 for narrow FoV,
(d) clear aperture: 2 cm or more, with a scalable fabrication process that can achieve larger sizes,
(e) spot size: within 20% of diffraction limit,
(f) in-band transmittance: 85% or better, including for all incident angles up to ±25°,
(g) electro-mechanical zoom time: 3s or less, and zoom range up to 5X.

The goal is to dramatically reduce size and weight versus comparable state-of-the-art conventional zoom lens systems, without reducing performance. Weight will be reduced to 25% or less, and axial length of the optical elements (excluding back focal length standoff distance) will be reduced to 15% or less than that of the conventional zoom lens set-up. The reduced weight and length should reduce time required for zoom adjustments. Initially, focal length tuning can be performed manually, but tuning speed should achieve the above target specification by the end of this effort. Longer-term goals include reduction of f/# (the f number which is a measure of the FoV of the lens set up) and increase in mechanical robustness to withstand vibrations, acceleration forces, and mechanical shocks associated with unmanned aerial system (UAS) takeoff and landing.

PHASE I: Determine the feasibility of, detail, model, and simulate an innovative approach for an ultra-compact lightweight, MWIR zoom imaging optic based on flat lens technology. Design, fabricate, and test in the laboratory a proof of concept to demonstrate the flat lens technology and its varifocal capability. Characterize performance based on the specifications outlined in the topic description. The proof of concept should have a clear aperture diameter of at least 4 mm, a zoom range of 5x, a wide FoV of f/2, in-band transmittance of 60% or better, and 96% polarization insensitivity. Design a compact MWIR zoom imaging optic to be fabricated and tested in Phase II. Use modeling and simulation to estimate its performance, including size, weight, and power. Develop a test plan and test procedures to be developed in Phase II. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Optimize the design of the prototype flat lens MWIR zoom optic based on the design from Phase I. Develop modifications that can improve performance and perform modeling and simulations. Design electro-mechanical lens housing and motorized control software for the zoom system. Fabricate the zoom optic and test it in the laboratory to demonstrate all the performance specification targets listed in the Description. Detail a scalable fabrication process that provides a roadmap toward cost-effective production and larger clear aperture systems. Study numerically the trade-offs of zoom optic performance between aperture size, numerical aperture (f/#), working bandwidth, transmittance, and FoV. Also investigate theoretically and experimentally the feasibility of extending the zoom range from 5X to 10X.

PHASE III DUAL USE APPLICATIONS: Transition the technology for U.S. Government use. Fully develop and transition the technology and methodology based on the research and development results developed for DoD applications in the various areas of anomaly detection, surveillance, and reconnaissance applications.

The commercial sector can also benefit from this innovative flat lens with very low SWaP in the areas of detection of toxic gases, environmental monitoring, and noninvasive structural materials monitoring and sensing.

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KEYWORDS: Low-aberration; Imaging optics; Flat lens; Zoom capabilities; Mid-wave infrared; MWIR; Metamaterials

N23A-T008 TITLE: Ultra-fast Full-Wave Photonic Simulation and Optimization

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy; Microelectronics; Directed Energy

OBJECTIVE: Develop novel ultra-fast simulation technology capable of speeding up full-wave electrodynamic simulation by 1,000 times. This ultra-fast simulation technology will be used to develop long-wave infrared (LWIR) lens that are 100 times thinner and lighter than today’s state-of-the-art LWIR optics and with fully customizable aperture sizes and focal length.

DESCRIPTION: Flat metamaterial optical devices provide a unique opportunity for producing compact and high-performance components for manipulation of light [Ref 1]. Such devices may be constructed through nanofabrication on a planar substrate, providing the possibility of replacing traditional diffractive components that are versatile for various defense and civilian applications [Ref 2]. Flat optics is particularly interesting in the long-wave infrared region because the lack of high-quality imaging optics. Traditional lenses are costly and bulky and possess limited aperture size in the infrared region. Developing integrated imaging optics in LWIR is of great interest especially for tactical surveillance and reconnaissance in this special range [Ref 3].

Metamaterial optical device is a 2D array of dielectric structures that is used to focus transmitted light to a single position directly in front of the device. Typically, these structures are emulated by simulating each dielectric unit cell individually to compute a phase and amplitude transmittance for each cell. While this approach makes for an approximation of the overall device performance, it would be useful to be able to simulate the entire device as a whole to capture the complete physical characteristics of the device structure. However, a simulation of this scale requires several hours or days to perform with a conventional CPU-based finite-difference time-domain (FDTD) method.

To get around the lack of sufficient computational power and to shorten the computation time, the typical compromising approach is to assume a constant phase and amplitude response from each cell [Ref 4], which are used to approximate electromagnetic fields in front of the device. This approximation leads to undesirably less accurate predictions [Ref 5], resulting in sub-optimal device performance. Various techniques, such as the optimization technique in Ref 6, have been attempted to correct for these errors and yet none have been completely successful.

Addressing the very time consuming computation and the accuracy of the modeling and simulation issues simultaneously for this type of complex optics is therefore paramount for designing and fabricating compact optics for LWIR imaging systems with stringent high-performance requirements. This topic seeks to exploit emerging computing hardware to develop ultra-fast computation algorithms to accelerate accurate simulation and uncompromising optimization of flat optics in the LWIR wavelength range. This topic seeks development of FDTD simulation that is at least 1,000 times faster than today’s open source and commercially available FDTD solutions. The developed ultra-high-speed FDTD solution is then utilized to model and simulate metalenses that reduce the computation time—by up to 1,000 times—relative to conventional FDTD methods [Ref 8]. The simulation solution should be able to simulate metalenses of multiple centimeters in optical aperture with optimization of imaging figures of merit such as focusing efficiency and Strehl ratio with respect to the unit cell design parameters. The metalens’ focusing efficiency should be higher than 95% over a broad wavelength range from 8–12 microns, and at least 100 times lighter and thinner than traditional state-of-the-art LWIR imaging optics [Ref 8]. Traditional FDTD [Ref 7] would take tens of hours to simulate the abovementioned structure. With the successful development of this algorithm, the same simulation should finish in about one minute.

PHASE I: Determine optimal hardware platform and computational resources required for centimeter-scale simulation of metamaterial lens. Identify both the starting device design based on material and geometry designs from previous experimental works, as well as the figures of merit to optimize and measure experimentally. Demonstrate feasibility and begin development of a working prototype of the software, to include demonstration of a near field calculation of 5 cm x 5 cm flat optics system with a simulation speed improvement of over 1,000 times when compared to CPU-based FDTD. Show consistency between these simulations and experimental demonstrations of the flat metamaterial optics in LWIR. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate, and validate the prototype. Incorporate adjoint-based optimization capabilities into the solver. Using adjoint-enabled gradient-based optimization, produce a prototype structure that maximizes the focusing efficiency over the spectral wavelength of interest using about 100 iterations. Demonstrate a significant improvement in device performance that surpasses that of conventional LWIR imaging systems.

PHASE III DUAL USE APPLICATIONS: Transition the technology for Government use. Further develop and refine the design of the simulation software and assist in adapting the simulation software for optimization designs of various photonic devices.

The commercial sectors such as the optics and camera industries can benefit from the reduction of the individual simulation time from several hours to seconds, meaning more parameters can be scanned and at greater resolution, allowing one to simulate structures at a larger scale, enabling full 3D modeling and simulation of an entire device instead of components, and running many jobs simultaneously in the cloud.

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KEYWORDS: Full-wave photonic simulation; Design optimization; Computational speed improvement; Metalens; Metamaterials; Lens

N23A-T009 TITLE: DIGITAL ENGINEERING - Generalizable Tactical Software AI/ML-informed Debloating

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy; Integrated Sensing and Cyber

OBJECTIVE: Develop capability that leverages artificial intelligence and machine learning (AI/ML) technologies to debloat tactical software to reduce support costs, improve run-time stability, and reduce cybersecurity vulnerability.

DESCRIPTION: Much modern software suffers from “bloat” that negatively impacts its maintenance costs, performance, and security. Commercial software tries to address wide audiences and focuses on programmer productivity, resulting in software with many indirections, libraries, and layers of abstraction. Government entities have not historically incentivized industry to produce minimal code bases, sometimes even basing funding on the number of source lines of code (SLOCs). Compounding this state of affairs, Naval Control Systems (NCSs) are built and upgraded over extended periods of time, resulting in systems containing tens of millions of SLOCs.

Exploratory research at the Naval Undersea Warfare Center has determined that significant bloat can be removed from these complex control systems. One impact of this bloat is cost associated with supporting excessive binary executable sizes. A more troubling consequence of software bloat is instability in the run-time tactical system. The presence of exploitable attack surfaces in the bloat within code is a third problem. Finally, excessive bloat has a commensurate impact on cost and time to perform system testing. As testing rarely exercises the total system, excessive SLOCs and binary executable sizes increase the likelihood of “escaped bugs,” software problems that are not seen until after system fielding. Escaped bugs require heroic measures to fix.

State-of-the-art research studies by subject matter experts in academia outline the approaches that can be taken to de-bloat and harden software systems. Yet there are few, if any, commercial programs to automatically de-bloat and harden software systems, due to commercial emphasis on productivity and software reuse.

The Naval Undersea Warfare Center (NUWC) has experimented with debloating tactical code, demonstrating the utility of such an effort. However, the exploratory debloating process conducted by NUWC was labor-intensive and tailored, making this sort of debloating cumbersome and unaffordable in the context of envisioned Continuous Integration/Continuous Delivery (CICD) capability fielding. The NUWC manual-intensive process seems amenable to being automated by use of AI/ML. Based on NUWC’s success, the Navy seeks a solution to develop a generalizable tactical software debloating capability informed by AI/ML.

There are multiple metrics for software debloating. The first metric is the number of SLOCs reduced or decreased in binary file size, as there can be some benefit to sheer reduction in the total system size. However, it has been shown that this quantity is misleading because debloat tools that perform hardening are often expected to increase the overall file sizes by including additional protections for cyber-resiliency. The second metric is the quality of bloat removal, where the bloat that has been removed substantially improves system stability and reduces cybersecurity vulnerabilities. For example, past research has used as a metric “code reuse gadget count reduction”, which measures the difficulty for an attacker to mount a gadget-based code reuse exploit such as return-oriented programming (ROP). However, realistic debloating scenarios have shown that even high gadget count reduction rates can fail to limit an attacker’s ability to construct an exploit and may even introduce new quality gadgets [Ref 2].

Thus, the quality of debloat metric should use “functional gadget set expressivity” and “special purpose gadget availability” to assess the utility of the gadgets available to the attacker rather than the quantity, as calculated using the Gadget Set Analyzer (GSA). The technology sought would have a threshold requirement of decreased functional gadget set expressivity and special purpose gadget availability by 10% relative to the untouched tactical system. The security metrics would identify the reduction in unique attack surfaces associated with bloat. Finally, the performance metric would characterize the improved performance associated with debloating as a modification to tactical computational time and memory usage. Similar metrics are expected to be derived for container, Linux kernel, and firmware debloat.

PHASE I: Develop a concept for a generalizable debloating capability powered by AI/ML. The concept must demonstrate feasibility to reduce the bloats in code, with potential to reduce attack surfaces and improve software quality according to the parameters in the Description. Feasibility will be demonstrated through analysis and modeling. The Phase I effort can be demonstrated on unclassified software the company feels is analogous to the complexity level of the target USW 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: Develop and deliver a prototype generalizable debloating capability powered by AI/ML for testing and evaluation based on the results of Phase I. Demonstrate that the prototype meets the parameters in the Description. The technology will be assessed over the course of Phase II by Navy software subject matter experts (SMEs) knowledgeable about the investigative effort to debloat Navy software.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. The final product will consist of a capability to debloat tactical software that leverages AI/ML to minimize the tailoring and labor that can be associated with a manual debloating approach.

The resultant technology will be used during system integration and production by the prime contractors producing Undersea Warfare Systems such as AN/SQQ-89A(V)15 and AN/UYQ-100. The generalized technology developed could also be used for debloating any complex software system, such as information technology systems, and critical infrastructure systems such as power generation, water purification, and healthcare delivery.

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KEYWORDS: Continuous Integration/Continuous Delivery; CICD; source lines of code; SLOCs; software debloating; cybersecurity vulnerabilities; instability in the run-time tactical system; artificial intelligence and machine learning; AI/ML

N23A-T010 TITLE: DIGITAL ENGINEERING - Sonar Dome Anti-Fouling Tracking and Prediction Tool

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Intergated Network Systems-of-Systems
OBJECTIVE: Develop a capability to collect, analyze, and predict levels of Tributyltin Oxide (TBTO) in deployed sonar domes.

DESCRIPTION: A sonar dome protects the acoustic transducers, to reduce noise and enable optimal sonar performance. Crucial to its function is that the dome does not foul. Historically, this has been done by imbuing sonar domes with Tributyltin Oxide (TBTO) during the manufacturing process. Research to prevent fouling has not developed an alternative that is qualified for the domes on surface combatants. Even when a new anti-fouling method may be identified, there will be scores of sonar domes imbued with TBTO, with decades of remaining service. A combatant is at sea for about eight years before maintenance carried out at dry dock. Conventional, off-the-shelf antifouling approaches do not work with sonar domes, because they are made of rubber.

The Naval Research Laboratory (NRL) has recently developed a rapid, non-destructive, and inexpensive method to measure TBTO (or other anti-fouling systems) in sonar domes while a ship is dry docked. This will provide, for the first time, the data necessary for a nuanced understanding of the anti-fouling efficacy, throughout its service life.

The Navy seeks technology that will enable central management of these measurements from USN sonar domes that are deployed to locations and environments around the world, together with an ontological framework to record pertinent information about the sonar dome, such as manufacturing details and service life history. It is also desired that the architecture of the proposed technology accommodate a methodology for predicting anti-fouling life and updated algorithms as data supports algorithm refinement. Development of an initial predictive algorithm could fall within the scope of this STTR topic.

The Navy seeks a centralized capability for collecting this information, populating an ontological framework with pertinent data (such as sonar dome manufacturing details and service life history) for each measurement, and predicting future TBTO levels to understand both:

1. When sonar domes will need to be replaced due to depletion of TBTO.
2. When it may be appropriate to reduce the amount of TBTO (or future anti-foulant) used in new-construction sonar domes with changes in dome material or anti-foulant.

The centralized capability will enable the Navy to minimize maintenance while also minimizing harm to the marine environment.

The framework described herein must include:

- A method to capture data from a measurement tool for utilization in a Fleet-wide physics-based model designed for modular updating manually via future re-assessment of an updated database.
- A graphical user interface (GUI) that displays tracked values of interest.

Examples of potential elements to this ontology are:

- Measured anti-foulant loading remaining in coating.
- Models of TBTO degradation as a function of time and combatant travel profile.
- Predicted remaining lifespan of sonar dome TBTO based on measurements and predicted travel profile.
- Updated physics-based model calculations.

Any additional ontological elements that would improve the model would be welcome.

The physics-based model shall also incorporate:

1. Input parameters, including service conditions, that may vary over a deployment. Variables of primary considerations are surface ocean temperature and salinity, but others may be added.
2. Capability to change the input properties, to accommodate updated material specifications and other improvements.

PHASE I: Develop a concept for a physics-based database and GUI for diffusion from a sonar dome that meets all the parameters in the Description. Demonstrate the concept is feasible through analysis, simulation, and modelling. Preliminary experimental data will be provided by NRL. 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 physics-based database and GUI for the TBTO collection and prediction capability. Demonstrate the prototype meets the required range of desired performance attributes given in the Description. Feasibility will be demonstrated through system performance with information from initial TBTO measurements that will be collected. Develop a Phase III commercialization plan.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Navy use as software to collate, analyze, and manage TBTO data collected and tested via a hardware measurement capability maintained by IWS 5.0. Demonstrate and report on performance during laboratory testing. This technology can be used in a wide range of products where measurements of toxins or other material dopants of specified loadings are collected and predictions of future state are dependent on numerous variables which are not entirely dependent on one another. With the appropriate modifications, it may be used to monitor performance of commercial antifoulant systems, particularly when a new system is being adopted. The technology would be of greatest use in cases where environmental impact of a substance is of national or global concern, particularly in water / wastewater management or aquaculture

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KEYWORDS: Sonar dome; tributyltin oxide; TBTO; anti-fouling for sonar domes; ontological framework; predicting anti-fouling life; water management; wastewater management; aquaculture

N23A-T011 TITLE: Innovative Optics for Wide Field of View Infrared Sensors

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics

OBJECTIVE: Develop innovative and affordable wide aperture optics technology for imaging sensors operating in the mid-wave infrared (MWIR) and short-wave infrared (SWIR) bands.

DESCRIPTION: Electro-optic and infrared (EO/IR) video imaging sensors (cameras) are widely used for situational awareness, surveillance, and targeting. The Navy is deploying such cameras in multiple spectral bands, covering both wide and narrow fields of view (FOV). Wide field of view (WFOV) cameras are particularly expensive as they employ large focal plane array (FPA) sensors and, to gather sufficient light, these cameras must have large aperture optics (lenses). In the infrared (IR), these lenses are especially costly, not benefitting from large commercial economies of scale as exists for camera lenses in the visible spectrum. Furthermore, because of the shallow depth of field inherent in such large aperture lenses, the optical elements (and the FPA) must be aligned to extremely tight tolerances in order to maintain the high resolution required. Tolerances for axial alignment on the single-micron level are not uncommon. In addition, the optical assembly must be rugged enough for shipboard deployment, maintaining its alignment in spite of operational shock, vibration, and extremes of temperature. Consequently, not only are the optical elements (lens elements) expensive, but the optical housing (lens barrel) is expensive as well. Finally, the precision assembly processes required to achieve such tight optical alignment are labor intensive and the labor is highly skilled in nature. The result is that such cameras are excessively costly.

The Navy needs an innovative technology for focusing IR light onto FPA sensors with high optical resolution. The goal is to dramatically reduce cost without compromising performance. A nominal cost reduction of 5:1 is desired for the optical assembly (based on the current state-of-the-art for conventional optics), which, for this purpose, does not include the material cost of the FPA but does include the optical elements, the optical assembly, and alignment of the optics with the FPA. A solution applicable to both the MWIR and the SWIR is desired. However, the technology may be demonstrated in either band, at the discretion of the proposer. A maximum effective aperture of f1.0 is desired with a 90° FOV and coverage sufficient for a 2k X 2k pixel FPA with 10 µm pitch. The light fall-off from FPA center to the corner of the FPA shall not exceed a factor of 2.0. The depth of field shall be sufficient to resolve single pixel targets. Note that all requirements apply at full aperture. Optical aberrations are acceptable provided they can be compensated for in post processing and provided that they are not so severe as to inhibit resolution of a single pixel target lying anywhere in the imaged field.

In demonstrating a solution, and in order to reduce cost, a large format FPA meeting the dimensions given above need not be included in the prototype. A smaller FPA (or multiple FPAs) may be used provided it can be shown that the required image quality defined above is achieved over the extent of the large format FPA. This effort anticipates a hardware solution for a single large format FPA that yields high image quality (resolution, dynamic range, noise, etc.) video capture in real time. Image capture shall accommodate a video frame rate of 30 frames per second. Solutions that attempt to re-construct images or combine images from multiple FPAs are undesirable. Predominantly software-based solutions – that is solutions based on extensive post processing of the captured image data will not be considered. Solutions incorporating electro-mechanical compensation of optical elements are permitted providing the compensation mechanism does not reduce the integration time available to the FPA. Any electro-mechanical components included in the solution must also be shown to have a (maintenance-free) life expectancy comparable to the FPA.

At the end of the effort the prototype shall be delivered to Naval Surface Warfare Center (NSWC) Crane Division. Included in the prototype will be the FPA (or FPAs) used to demonstrate the image quality obtained by the solution, and any controllers, power supplies, housings, coolers, output interfaces, special processing hardware, custom software, fixtures, and specialized tools necessary to replicate testing of the prototype. A cost estimate for production and integration of the solution will be performed to assess the reduction in cost associated with the technology. The cost assessment shall be benchmarked to the cost of a conventional optical design.

PHASE I: Develop a concept for a large aperture optical system that meets the objectives stated in the Description. Demonstrate the feasibility of the concept in meeting the Navy's need. Analyze the effect on image quality and predict the benefits for cost reduction. Feasibility shall be demonstrated by a combination of analysis, modeling, and simulation. The Phase I Option, if exercised, will include an initial sensor specification, test specification, and capabilities description necessary to build and evaluate prototype hardware in Phase II.

PHASE II: Develop and demonstrate a prototype large aperture optical system for imaging IR sensors based on the concept, analysis, preliminary design, and specifications resulting from Phase I. Demonstration of the large aperture optics technology shall be accomplished through test of a prototype in a laboratory or sheltered outdoor environment. At the conclusion of Phase II, prototype hardware shall be delivered to NSWC Crane along with complete test data, installation and operation instructions, and any auxiliary software and special hardware necessary to operate the prototype.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology for Government use. Develop specific optical designs for Navy sensor systems. Establish hardware configuration baselines, produce support documentation, production processes, and assist the Government in the integration of the optical technology into existing and future WFOV imaging sensor systems.

The technology resulting from this effort is anticipated to have broad military application. In addition, there are law enforcement and security applications. Scientific applications include satellite and aerial imagery.

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KEYWORDS: Video Imaging; Imaging Sensors; Wide Field of View Cameras; FOV; Large Aperture Optics; Depth of Field; Optical Resolution

N23A-T012 TITLE: Atmospheric Aerosol Model and Data Collection Over the Marine Boundary Layer for Imaging/Radiofrequency (RF) and Laser Beam Propagation

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Directed Energy (DE)
OBJECTIVE: Develop a periscope imaging, electronic warfare, and High Energy Laser (HEL) beam propagation model over the marine aerosol boundary layer for the integration of propagation modeling software into a system that will investigate absorption and scattering properties of marine aerosols, the interplay between aerosols and turbulence, and the impact on imaging and electronic warfare (EW).

DESCRIPTION: The Navy seeks technologies that are oriented toward a deeper experimental and theoretical understanding of maritime turbulence and laser beam propagation in the marine boundary layer (MABL). Ocean evaporation is occurring within a very thin molecular layer at the surface. However, there are indications that instantaneous turbulent structures in the ocean and marine atmospheric mixing layers play a critical role in determining the water vapor flux and near surface particulate (aerosol) concentrations. The Navy is looking for a greater understanding of the marine aerosols and their impact on turbulence on periscope imaging, EW, and HEL beam propagation. Aerosol properties will be studied using available instruments such as particle counters, sun photometers, Short Wave Infrared (SWIR) cameras, Delayed Tilt Anisoplanatism (DELTA) camera, RAMAN scattering instrument, and instruments for aerosol absorption quantification. This proposed study will help improve the current atmospheric models for submarine imaging/ EW and HEL horizontal beam propagation within the MABL. Recent efforts have been aimed at characterizing the turbulence in the marine wave layer and surface layer marine boundary layer. The aerosol and turbulence models developed through experimental measurements will be used to model nonlinear effects such as thermal blooming in a marine environment on both continuous and pulsed lasers. Additionally, image contrast reduction due to marine aerosols will be studied and the prospect of determining aerosol loading from degraded images will be investigated. In this proposed study and model, we are looking for an innovative instrument development to understand the nonlinearity of the atmosphere like thermal blooming and RAMAN scattering. The model developed shall include atmospheric nonlinearity and its effects on a complete model of Imaging and HEL beam propagation that includes turbulence and aerosol effects. The model will be extremely useful for development of adaptive optics and beam control systems to maximize power in the bucket in case of horizontal propagations.

In this STTR topic the proposer shall explore the use of a small Unmanned Aircraft System (sUAS) and develop and execute sUAS flight profiles for marine Sea-Air turbulence and aerosol interface research. Marine boundary layer profiling at different heights shall be used to enhance the multi-target capability of a customer’s imaging and on HEL as well as the HEL subsystem’s including laser range finders (LRFs), and beacon and tracker illuminator lasers. Additionally, such profiling in combination with radiative transfer and Imaging and HEL propagation models such as the Laser Environmental Effects Definition and Reference (LEEDR) and High Energy Laser End to End Operational Simulation (HELEEOS) codes shall enhance post-engagement HEL forensic analysis such as target effects in the marine boundary layer. Current measurement techniques, such as Laser Doppler Velocimetry (LDV), are limited to resolutions of 0.5 meters or greater and fall short of the required millimeter level resolution. A new type of spectral imaging modality and instrumentation is required that will increase our understanding of ocean evaporation and lead to better tools for measuring and modeling the near-marine boundary layer for optical and radio frequency Naval applications. This generalized understanding will significantly enhance beam optic directors, adaptive optics, and other turbulence mitigating techniques to enhance the reach and effectiveness of communication as well as defensive and offensive high energy laser engagement in the marine aerosol boundary layer.

PHASE I: Provide a concept to solve the Navy’s problem, and demonstrate the feasibility of that concept. Develop the general model concept and instrumentation setup over MABL to collect data for the prediction atmospheric non linearity and its effects such as marine thermal blooming and other marine non linear effects due to image degradation and HEL horizontal beam propagation through the MABL < 60 ft above marine surface. Develop clear model concepts and non-linear MABL data acquisition setup to remotely measure temperature, pressure, and marine aerosol for the acquisition MABL model validation and verification. Phase I Option, if exercised, will include the initial model and capabilities description to build a prototype model and validation of the proposed model by data collection over marine surface in Phase II.

PHASE II: Develop the marine aerosol on image degradation and HEL Beam propagation model and data collection analysis software which shall be delivered to Navy. The MABL model shall be used for submarine imaging system and target detection and tracking, HEL target lethality improvement and integration with submarine HEL beam control software for evaluating HEL horizontal beam propagation and image degradation through marine aerosol environment. The model shall be used for system performance evaluation based on the results of Phase I concepts. Describe how evaluation can be accomplished through modeling or non-linear analytical methods to demonstrate that the technology does have the potential to meet Navy imaging, such as image degradation, target detection, target identification, and HEL performance goals such as remotely profile horizontal turbulence profile mapping, temperature, and pressure profile mapping.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy submarine platforms as a metrological tool for marine wave boundary data collection.

The non-liner marine aerosol effects on Submarine Imaging and HEL beam propagation model and innovative data analysis technology such as Fourier Optical analysis have both commercial and DoD applications. This technology can improve a commercial ship’s localized weather prediction and update the weather software for safe operation. Additionally, improved LIDAR detection for range at day, night, and all-weather conditions is beneficial for both commercial and DoD applications. The nonlinear marine aerosol metrology model system could also find applications in trace gas and pollution monitoring.

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KEYWORDS: RAMAN; Laser Beam Propagation; Marine Aerosol Environment; Marine turbulent boundary Layer; MABL; Thermal blooming; Laser Environmental Effects Definition and Reference; LEEDR

N23A-T013 TITLE: Unmanned Underwater Vehicle (UUV) Sensor Data Transformation Tool

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy
OBJECTIVE: Develop a software tool to transform and create synthetic sensor data from information received by a different sensor.

DESCRIPTION: Modern platforms may contain a variety of sensors such as sonars of varying frequencies, cameras, and magnetic sensors. Often times, target information is collected by one or more sensors, but not by all of the sensors. This can lead to an increased number of test runs against targets to ensure each sensor, and associated algorithms, have an opportunity to collect target information in a variety of environmental conditions. The Navy seeks an innovative tool to transform sensor and metadata from a given system or frequency into realistic synthetic data from another sensor. For example, the transformation tool should be capable of transforming real data collected by a side scan sonar (SSS) into synthetic data representative of other sensor modalities, such as an SSS of a different frequency, a forward-looking sonar (FLS), or an electro-optical camera. In addition, this tool would be able to reconstruct a synthetic target in different orientations, with varied degrees of burial, and with adjacent imagery in varying bottom types (e.g., complex, noncomplex).

The information created with this synthetic data generation tool will be used to develop and train automatic target recognition (ATR) algorithms. Sensor data to be generated should use complex physics-based models and represent objects in the subsea environments including mine-like objects. Providing realistic synthetic data will improve ATR, operator responses, reduce operator uncertainty, and improve decision-making. Machine Learning (ML) synthesis tools can enable development of realistic synthetic sonar for use with simulations. ML approaches are being leveraged for image and video processing applications, but a limiting factor is the availability of training data. High-quality synthesis approaches that utilize ML can also provide an alternate means to creating the large volumes of training data that are needed to ‘teach’ a deep learning algorithm.

Sensors of interest include acoustic, optical, and magnetic sensors. Solutions must also be compatible with, and easily applied within Navy Expeditionary user displays and interfaces for conducting in-situ mission monitoring and post mission analysis.

The proposer will analyze sensors and data formats, and develop data transformation solutions capable of incorporation onto Nvidia Graphic Processing Units (GPUs), ensuring compatibility with user interfaces employed in legacy Navy Expeditionary UUV systems.

Synthetically generated images and data should be quantifiably similar to real data produced by the target sensor in terms of acoustic and optical reflectivity, and magnetic moment. That is, synthetic data scored as 'similar' should have ATR outcomes representative of real sensor data. ATR performance will be measured in Phase II. Methodologies and metrics for similarity scoring are encouraged as components of validity test proposals.

PHASE I: Develop a concept for an innovative software solution capable of generating synthetic sensory data and metadata. During the Phase I base effort, the Government will provide a list of commercial sensor type, representative calibration targets and display/meta-data for sensors of interest to enable analysis of data structures and determination of data transformation feasibility and limits. Demonstrate the feasibility of the concept to successfully confirm that data from a real data set is transformed into synthetic data as if collected by other sensor modalities to include different sonar frequencies and types (e.g., FLS, Gap-filling sonar (GFS), Real Aperture Sonar (RAS), and Synthetic Aperture Sonar (SAS)), Magnetometer, and Optical Sensors. The Phase I Option, if exercised, will include initial design specifications and a capabilities description to build a prototype in Phase II.

PHASE II: Develop, demonstrate, and deliver a software prototype system capable of creating synthetic sensor data and metadata from sensors identified in Phase I efforts for testing and evaluation; the prototype system will be compatible with and suited to future integration as a module of the Common Operator Interface, Navy (COIN)/NEXUS user interface. Develop the prototype sensor transformation tool. Synthetic data generated using this tool will be evaluated against baseline ATR algorithms it to determine if it meets Navy performance goals described in the Phase II SOW. Use operationally representative data for the demonstration. Identify performance and technical requirements to be met during evaluation. Prepare a Phase III development plan to transition the technology for Navy and other potential commercial use.

In Phase II, develop and demonstrate performance of a prototype software module, incorporating their technical solution for synthetic data generation for sonar, optical and magnetic moment data. The transformed data set build time threshold is 3:1 with an objective of 24 hours or less, for distribution to fleet operators or other programs.

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the successfully matured technology as a software module of the Common Operator Interface, Navy (COIN)/NEXUS user interface as a component of Navy Expeditionary UUV systems. Technical support to further troubleshoot, further refine and better adapt the Phase II prototype deliverable will be provided by the contractor as the Navy conducts the full range of testing and evaluation of the module as a software upgrade to the UUV systems. Navy testing and evaluation will be included comparative analysis of real-world data sets collected by the Navy where actual representative targets have been added, with synthetically generated data sets which add the targets to the environment. ATR algorithms will be run on both data sets to verify effectiveness of the synthetic data generation tool. Refinements by the contractor during Phase III may include, but are not limited to, software certification for cyber security compliance, and an addition or improvement of features and attributes to enhance user interfaces.

Application of the product may reasonably be expected to extend to commercial contexts such as automated object recognition for autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs) engaged in maritime salvage and field inspection for the oil and gas industry.

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KEYWORDS: Mine Countermeasures; MCM; Synthetic Data; Software; Unmanned Undersea Vehicles; Mines; Navy Expeditionary; Collection of target information on UUVs

N23A-T014 TITLE: DIGITAL ENGINEERING - Automated Knowledge Base Extraction and Student Assessment

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy
OBJECTIVE: Develop an automated capability to generate exams with answer keys using Artificial Intelligence or Machine Learning (AI/ML)-powered data mining for Undersea Warfare (USW).

DESCRIPTION: When systems are updated, development of training materials for the updated system can be labor-intensive and can take significant time to prepare. Meanwhile, students are being taught using potentially deprecated information. This is particularly true when the system is complex. The problem is compounded when updates occur frequently. USW system operation is a skill that is highly perishable, increasing the importance of accurate, updated training products. The importance of USW to national security necessitates system updates on a frequent basis. This makes developing current, up-to-date training materials for the updated capabilities key to harnessing the power of these systems.

Today, over 450 sailors graduate annually from Surface Combat Systems Training Command San Diego (SCSTC-SD). To stay current with the ongoing efforts to continually update USW related course materials, exams are currently still manually produced, administered, and graded by hand, which consumes numerous man-hours that could be better spent providing course instruction and running tactical scenarios in high fidelity virtual trainers. Creating a Surface Force USW Knowledge Bank to augment Instructional Design, with up-to-date USW References, would significantly decrease this workload.

The Navy seeks a solution that can (1) mine documentation for existing capability associated with the SQQ-89 and UYQ-100, (2) autonomously develop a core USW training knowledge base with associated exam questions and answer keys, and (3) automatically identify deltas to the core knowledge base associated with approved capability improvements and appropriately adjust the core knowledge base to remove deprecated content.

AI/ML techniques such as natural language processing (NLP) and data mining have improved markedly in recent years. The Navy seeks a technology that automatically generates tests and answer keys from functional description documents (FDDs), concepts of employment (CONEMPs), and concepts of operation (CONOPs), and other USW References created during capability developments and deployment. The AI/ML technology will demonstrate capability at a complexity level that is analogous to the target USW systems but need not be a military system. The Government will provide data and specifications as needed to demonstrate the capability.

Utilizing various USW References including the FDD, CONEMPs, and CONOPs created during capability developments, this innovative tool would utilize AI/ML to search these references and generate an automated testing function. This tool would produce a test bank comprised of applicable and correct questions, generate an answer key, grade, and provide test score results as applicable. Automated exam generation capability, based on material(s) of interest, does not currently exist due to the complex and changing system requirements and reference updates. This tool will also appropriately adjust the core knowledge base to remove deprecated content.

There is currently no technology available that smartly mines data from selected materials to document, categorize, and interpret information then generate up-to-date exams, and subsequent administration. Furthermore, current technologies do not allow for the interpretation and evaluation logic to verify that sailors are fully understanding and experiencing the intended system improvements.

USW reference resources are drafted and finalized over time and not necessarily in a prescribed order as they are continuously updated. Vendors provide the FDD outlining the capability of the system, displays, unique features, operating instructions, etc. However, the FDD does not explain how the updated system will function on deployment or how the sailor would employ the system specifically for anti-submarine warfare (ASW). The schoolhouse instructors manually translate the FDD into training material by creating a Modernization Training Team PowerPoint deck for training. AI/ML could be utilized to glean appropriate training materials from the FDD more efficiently, and effectively, than an instructor can manually.

The CONEMP provides a big picture look regarding how the sailor should use this updated system capability at a high level specifically, what is the employment and how this fits into the totality of tools at their disposal. The information in this document must also be included in the repertoire of training materials. As system engineers evaluate the system, they generate the CONOP which drills down into the details explicitly aimed at how to hunt for submarines. It describes exactly how the operator should use the system for this specific purpose. An AI/ML tool could be used to continuously mine for appropriate course material incorporating the operating requirements of the system related to the overall ASW process.

While AI/ML can be utilized to mine course materials from the FDD, CONEMP, CONOPs, and existing training PowerPoint documents, a more tailored and unique AI/ML capability would be necessary to evaluate the more subjective issue of whether sailors are understanding how to use the new system attributes specifically for ASW. AI/ML would need to be utilized to generate training materials and questions designed to analyze sailor understanding of the system nuances and how it works within the larger platform for ASW.

The School House gets the FDD with a copy of the code associated with the update/upgrade. They do not have CONEMP or CONOP immediately. As these documents and additional USW references, like Operator Employment Guides, become available over time, the instructors will need the flexibility to engage the AI/ML tool to include these materials in ongoing training course material updates. The new technology will be introduced in parallel with capability fielding and provide training personnel with the most current information to train students. This will increase the speed at which the Fleet can adopt transformational capabilities to maintain a warfighting edge. The threshold would be reducing the delay specific to developing training products by a factor of two.

PHASE I: Develop a concept for an automated capability to generate exams with answer keys using AI/ML-powered data mining that meets the parameters in the Description. Demonstrate that the concept can feasibly meet the requirements through analysis and modeling. 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 automated capability to generate exams with answer keys using AI/ML-powered data mining. Demonstrate functionality under the required service conditions. Demonstrate the prototype performance through the required range of parameters given in the Description. The prototype will be tested by Government subject matter experts (SMEs).

PHASE III DUAL USE APPLICATIONS: Support the Navy in transitioning the technology to Navy use. The final product will consist of a capability to generate exam questions and answer keys from system documentation, generate delta questions and associated keys, and appropriately adjust the core knowledge base to remove deprecated content. The resultant technology will be used and tested by the training and Integrated Logistics Support (ILS) team supporting Undersea Warfare Systems such as AN/SQQ-89A(V)15 and AN/UYQ-100.

The technology developed could also be used to develop training products for any complex skillset subject to rapid change due to policy or technology changes. Examples of such complex skillsets include law enforcement and air traffic control.

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KEYWORDS: Automatically generate tests and answer keys; Artificial Intelligence and Machine Learning; AI/ML; natural language processing; NLP; functional description documents; FDDs; concepts of employment' CONEMPs; concepts of operation; CONOPs

N23A-T015 TITLE: Scalable Net-Zero JP-10 Production from Non-Fossil Fuel Resources

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy

OBJECTIVE: Develop a scalable prototype system to produce JP-10 from non-fossil sustainable energy resources.

DESCRIPTION: The objective is to develop a scalable synthetic approach to producing JP-10 that meets military specification, MIL-DTL-87107E from non-fossil sustainable energy resources such as carbon dioxide (CO2), biomass, and waste products. JP-10 is primarily composed of exo-tetrahydrodicyclopentadiene, C10H15, and synthesized by the hydrogenation, isomerization, and separation and purification of dicyclopentadiene, a petroleum-based resource. The proposed synthetic process may be chemical or bio-manufacturing in nature, and must be low in temperature (not to exceed 500 °C) with pressures not to exceed 600 psi. Initial prototype demonstrations of the technology will be up to 1 gal/day. For future design and scaling purposes the objective will be to synthesize 1,000 gal/day of finished JP-10 from a process that can be placed in a Conex shipping container.

PHASE I: Define, develop, and perform initial laboratory assessment of the proposed synthetic process to validate the technical feasibility of the synthetic approach to producing JP-10 that meets MIL-DTL-87107E. Perform analysis of the fuel and determine initial process selectivity. Based on the laboratory approach, define and develop a concept for a modular, scalable JP-10 synthetic process, that can meet the performance and design specifications listed in the Description. Develop a Phase II plan.

PHASE II: Develop a prototype process based on the work achieved in Phase I. The prototype will be designed to produce 1 gal/day of finished JP-10 that meets MIL-DTL-87107E. The prototype will establish performance parameters and proof of concept for development of full-scale process in Phase III.

PHASE III DUAL USE APPLICATIONS: The integrated 1 gal/day prototype process will provide equipment, process, design criteria, energy and material balance, and establish operational performance parameters. This data will be used to provide the design criteria for transitioning the technology to larger capacities. A 100-1,000 gal/day process will be developed and tested in Phase III. The design criteria and performance parameters will enable the system to be designed into a Conex container for transport.

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KEYWORDS: JP-10; Fossil Fuel; Prototype; Sustainable; Energy; Synthesis

N23A-T016 TITLE: Lightweight Turbogenerator for Vertical Take-off and Landing Unmanned Aerial Systems- in Marine Environments

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy;Integrated Network Systems-of-Systems

OBJECTIVE: Develop a lightweight (prioritizing weight above efficiency) integral turbogenerator in a compact package intended for embedded integration into a Vertical Take-off and Landing Unmanned Aerial System (VTOL UAS) for support of high-power conditions on takeoff and landing.

DESCRIPTION: Current VTOL UASs in development, and concepts being pursued by both commercial and military operators, require high-power delivery on takeoff and landing segments that can be delivered by small turbogenerators also in development. At small scales, around 50 shaft horsepower (shp) output, turbines with centrifugal compressors can provide high specific power but are typically less efficient than equivalent power reciprocating engines. Fabrication of turbines without the need to couple to a low-spool shaft for thrust generation, and instead coupling to a high-speed generator, can provide a path toward delivering high power levels during VTOL mission segments. New hybrid power architectures and electrical components can then support a serial or parallel propulsion system that could leverage the very low Brake Specific Fuel Consumption (BSFC) of the primary reciprocating engine, and provide additional power via a small lightweight turbogenerator that could generate sufficient power for the short-segment VTOL maneuvers, with much lower requirements on specific fuel consumption due to the short (on the order of one minute) durations involved.

Modifying the cycle of a turbogenerator to optimize the design for high power output without concern for SFC could simplify the design as well as reduce the cost of the unit by lowering aerodynamic design tolerance requirements, and reducing the thermal cycle requirements in terms of pressures and temperatures, as well as simplifying the mechanical design without the need to couple a low-speed turbine to generate thrust.

KEY SMALL AUXILIARY LIGHTWEIGHT TURBOGENERATOR ENGINE (SALT-E) PARAMETERS

- Multi fuel operation on F-24, JP-8, JP-5, Diesel
- Specific fuel consumption not to exceed 3.0 lb / hp-hr while operating at maximum design power level at 15,000 ft MSL STD day
- High specific power > 2.0 shp/lb turbine output (Threshold), 4.0 shp/lb (Objective) including the generator system (does not include power control unit or fuel system)
- System must include integral generator operating at peak efficiency of > 90%
- Cold, electric remote start capability (-20°C) without ground support
- Capable of operating in marine environments for sea-based operations
- System should include air bearings to allow for oil-free operation and that include material systems that are marinized and capable of operation in sea-based environments with a time between overhaul (TBO) target for the design of >1500 hrs
- Recuperators should be included in the design to increase BSFC (lbm/hr/kW-electric output) at an appropriate effectiveness (target minimum of 70% effectiveness) and weight
- Recuperator temperatures that can support turndown to power level angles (PLA’s) with an objective of 30%
- Capability of high specific temperature materials for the turbine wheel should be included
- Multi-orientation capability: 10 minutes continuous operation at maximum power with a change in orientation of 90 degrees from about a horizontal axis without degradations to operability, durability or shaft power output.
- Demonstrate a minimum of 150 hr durability for initial test articles

- Must be capable of continuous operation at peak load for 24 hours
- Unit must be capable of a minimum of 14 shp output (at the turbine shaft) and not more than 60 shp at sea level standard day conditions

PHASE I: Develop a test unit turbine section with a measured output of 14 - 60 shp continuous power output with a specific power of >2.0 shp/lb for the turbine system. System should include design and consideration of air bearing material systems and designs compatible with marinization requirements for operations in salt spray environments.

PHASE II: Integrate the turbine with the generator and demonstrate a fully integrated electrical machine capable of operations with simulated load profiles with controlled power output for supporting a VTOL hybrid power system. The combined unit should demonstrate continuous performance for up to 12 hours with logistical fuels.

PHASE III DUAL USE APPLICATIONS: Demonstrate the unit in a VTOL UAS flight test asset in a hybrid power system demonstration. Ground testing in an altitude cell will confirm altitude capability up to 15k ft MSL altitude. Flight testing will demonstrate the controllability of the unit and the viability of the hybrid power architecture.

Multiple commercial entities are developing, and have interest in small VTOL UAS for delivery of medical and other supplies to remote areas. Several capabilities exist that are less robust, and less capable than what a power turbine could enable in terms of payload and range capabilities, and in inclement weather. Likely there would be significant commercial interest in the technologies and capabilities developed in this type of power unit for both UAS and portable ground power applications.

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KEYWORDS: Turbogenerator; turbine; generator; recuperator; vertical take-off and landing; VTOL; hybrid; propulsion; hybrid-electric; hybrid propulsion; unmanned aerial system; UAS

N23A-T017 TITLE: Coherent Sensing Approaches for Dynamic Spectrum Allocation

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): FutureG; Trusted AI and Autonomy

OBJECTIVE: Design a distributed, coherent sensing solution to generate a spectrum map of available channels in sparse or dense spectral environments for channel allocation in a decentralized multi-hop network. Develop a scheme for sharing spectrum sensing results across the network for all channels to reach distributed consensus on the spectrum map between multiple geographically-dispersed nodes.

DESCRIPTION: Wireless multi-hop networks, and the understanding thereof, are key components to military and commercial communications. These networks are non-centralized, highly dynamic, and often either sparse or dense. With wireless communications and networking now necessitating dynamic spectrum allocation, such as with fifth generation (5G) and sixth generation (6G) cellular technology, military and commercial users must develop a more coherent approach to understanding spectral environments for maintaining reliable connectivity.

There are many signal processing solutions for detection and classification of spectral energy, such as those based on machine learning (ML). Standard ML metrics are often used to evaluate the accuracy of these techniques, such as number of false positives/negatives. System performance may also be quantified with temporal metrics such as latency and speed. While being agnostic to any particular sensing approach is the objective, it may be through the course of this STTR topic that a greater understanding of ML characteristics specific to the radio frequency (RF) modality is a key component to coherently linking multiple, geographically-dispersed sensing systems for the complete spectral mapping that fully supports dynamic allocation in sparse and/or dense environments. Indeed, sharing ML data model updates instead of in-phase and quadrature (I/Q) data is much more efficient. An adequate understanding to baseline spectral activity can be achieved through sensing at a single node, but distributed spectrum sensing would provide much greater fidelity on activity for dynamic spectrum allocation. Metrics similar to those used for quantifying accuracy and performance of a single node may also be used for evaluating these distributed sensing systems with multiple nodes.

Overcoming the coherence challenges behind a distributed spectrum sensing approach would enable a network-wide mapping of available channels. This awareness of the spectral environment would then inform proper channel allocation for resilient communications that support both military and commercial users. It would also enable adaptation within the spectrum, as well as identification of primary and secondary users. The solution to these problems must be computationally efficient and require little overhead to share sensing results/updates to nodes across the network. The goal is for coherency to be as agnostic to the sensing technique as possible.

This STTR topic will develop the foundational mathematical analysis to address coherence for distributed sensing in dynamic spectral environments. This topic also seeks an initial design of a methodology for disseminating results and awareness across the network to achieve distributed consensus among the sensing nodes for applications such as adapting communications within the spectrum and identifying primary and secondary users. The innovation and focus is on solving coherency issues in order to map out spectral environments for dynamic spectrum allocation, and on a means for efficiently sharing results to multiple nodes across the network to reach a desired end state of distributed consensus on spectral activity for dynamic allocation.

PHASE I: Conduct analysis to design an approach for coherent distributed sensing. Use this analysis to inform and demonstrate a proof of concept that provides a network-wide mapping of available channels. Perform a trade study and literature survey on sharing results for distributed consensus of spectral activity.

PHASE II: Refine, test, and prototype a scalable, mathematically-founded approach to coherent distributed sensing for network-wide mapping of available channels with means for sharing results/updates across the network to reach consensus amongst the nodes.

PHASE III DUAL USE APPLICATIONS: Support knowledge transfer and demonstrations/testing of the capability developed as a result of Phase II. The transition of a spectral mapping capability will help both military and commercial users with spectrum sharing and dynamic spectrum allocation amid the current proliferation of 5G, and future proliferation of 6G, communications and networking technologies. The envisioned coherency techniques for distributed sensing and means for disseminating consensus to enable dynamic spectrum allocation can provide many opportunities with military and commercial transition.

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KEYWORDS: Distributed Sensing; Network Mapping; Dynamic Spectrum Allocation; Spectrum Sharing; 5G; 6G; Wireless Communications; Distributed Consensus; Wireless Multi-hop Networks

N23A-T018 TITLE: Reliable Hydroxyl-Terminated PolyButadiene for Rocket Motors

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Hypersonics
OBJECTIVE: Establish combined modern analytical methods and a resultant predictive model for characterizing Hydroxyl Terminated PolyButadiene (HTPB) polymer binder resin in parallel with chemical cure, mechanical properties, and aging assessments, to support the successful development and use of military grade HTPB in existing and emerging solid rocket motors. The combined analytics and predictive model will reliably correlate binder resin chemical and physical properties with gum stock and formulation quality, provide key characterization parameters leading to updated military specification(s), and improved sourcing of HTPB for successful manufacture of rocket motor, ejection seat, and related propellants.

DESCRIPTION: The DoD has a need for proper analytics coupled with predictive material models for Hydroxyl Terminated PolyButadiene (HTPB) as used in rocket motors and other energetic formulations. Even when meeting military specifications, the binder resin, often and unpredictably, suffers from a too short and variable pot-life, slow and incomplete curing, poor gum stock mechanical properties, and poor aging behavior. As a result, DoD propellant production is often greatly hindered. As the need for more of this DoD-specific HTPB binder resin continues to grow, the fundamental chemical and physical properties of this polymer that lead to desirable rocket motor formulation characteristics remain poorly understood.

One major challenge for HTBP variants used in energetic formulations is that there are several ways to meet outdated military specifications (WS 20700, dated June 1981) that do not define necessary formulation-enabling chemical properties. An HTPB lot can meet specifications as a monodisperse straight-chain, telechelic polymer, or as a complex mixture of variable length, distribution of branches, and reactive sites. Ultimately, this variability leads to inconsistent and unwanted end use behavior. For instance, the variability in branching and the locations of the hydroxyl groups greatly affects how the polymer cross-links, which is magnified by other ingredients when formulating a rocket motor grain. Another example of the problems facing end users of HTPB binder is that processing techniques and the variability in the distribution of reactive sites greatly change the effectiveness of antioxidant protocols when formulating. These are only two examples of the problems associated with the currently available supply of HTPB. OSD and the DPA Title III office recognized the inadequacy of the weapon specification test requirements in determining whether any given lot of HTPB will work sufficiently in a propellant formulation and as such recommended additional tests be performed [Ref 1]. Further, the hydroxyl value of the product obtained from the current, domestic supplier appears to have decreased from historical levels upon attempting to target a lower hydroxyl functionality initially sought for prior program requirements. Concurrent with this change, formulators are finding it even more difficult to consistently produce a propellant that meets their requirements due to the polymer not having sufficient molecular weight or functionality fraction to permit the manufacture of a robust propellant, especially for air-launched applications.

To date, private industry has been unable to solve the technical challenges associated with analytical methods development, detailed understanding of the chemistry, reaction kinetics, safety, reproducibility, and scalability in order to produce a reliable HTPB variant and associated specifications. While there have been prior efforts to develop a greater understanding of the HTPB polymer characteristics [Refs 2-5], to date there has been no definitive model developed using appropriate, modern analytics to correlate polymer structure to performance. Future sources and suppliers of HTPB for energetic formulation use will require this type of analytically driven HTPB predictive model to inform updated military specifications and production practices.

PHASE I: Identify and/or develop combinations of key analytical methods for correlating HTPB polymer system chemical and physical characteristics with gum-stock and formulation end use properties leading toward development of a strong predictive tool. HTPB samples of varying quality should be obtained from the Government and other contractor rocket motor manufactures to assist in Phase I material analytical method development efforts. The quality of the HTPB should not be defined as simply “good” or “bad” but will be assessed by quantifiable data pertaining to pot-life, degree of chemical cure, oxidative susceptibility, mechanical properties, specification, and any other relevant test results that relate binder ingredient characteristics to formulated rocket motor characteristic requirements. Generate needed characterization data otherwise unavailable from Government and other sources. Phase I should culminate in a planned framework approach to building a predictive model that correlates HTPB chemical, physical, and any other relevant properties to resulting gum-stock and formulation characteristics, describing the analytical methods and characteristics to be used and validated in Phase II.

PHASE II: Refine HTPB polymer analytical methods and perform cure studies and aging assessments as needed to fully develop and validate the predictive model. The model should incorporate the capability to predict cured polymer gum stock mechanical properties, cure characteristics including pot-life, and aging characteristics based on a suggested set of analytically generated chemical and physical properties data. Make final model modifications based on validation studies and complete model development. The model will serve to ensure that a fully tested lot of HTPB, using the newly developed and defined set of analytical characterization tests, will meet required gum-stock pot life, cure profile, and aging characteristics.

PHASE III DUAL USE APPLICATIONS: Using the developed HTPB model, work with Government and other contractor entities, as applicable, to develop robust processing and controls to produce HTPB at pilot scale meeting desired material chemical and physical characteristics as previously identified that lead to successful gum stock formulations (i.e., meeting various exemplar rocket motor formulation specification requirements). Additionally, the predictive model and associated data will be used to assist in development a modern DoD specification for HTPB. Outcomes from work under this STTR topic would likely benefit other industrial/commercial uses for HTPB type polymer resins where similar chemical/physical property characteristics are critical to material performance (i.e., rubbers).

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KEYWORDS: Hydroxyl-Terminated Poly Butadiene; HTPB; predictive model; polymer analytics; material specification; Solid Rocket Motor; SRM; propellants; explosives; energetic materials

N23A-T019 TITLE: Electrochemical Machining of Turbine Engine Components

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Advanced Materials

OBJECTIVE: Develop an electrochemical machining process which has lower up-front non-recurring engineering expenses while still enabling fast material removal for a reduction in machining times of turbine engine components and enabling more fuel efficient gas turbine engines.

DESCRIPTION: Electrochemical machining (ECM) processes have been utilized for subtractive machining of aerospace materials such as nickel and titanium alloys. The process is particularly attractive due to its high metal removal rate in tough or heat-resistant materials common to the requirements of propulsion and power generation engines. The surface quality provided by ECM is also advantageous due to the low roughness and no heat affected zones or recast layer. In addition, the lack of electrode wear can lead to high process repeatability and lower production costs.

ECM is relevant for a number of Navy propulsion needs, including compressor and turbine airfoils, integrally bladed rotors (IBRs) or bladed disks (blisks), cases, disks, and combustor components. IBRs and blisks, for example, are particularly expensive for 5-axis Computer Numerical Control (CNC) machining due to challenging materials (e.g., Ti6242, Inconel 718), tight geometric tolerances on 3D surfaces (e.g., +/- .001-.003”), and smooth surface finish requirements (e.g., =10 µin Ra). In addition, new IBR and blisk designs feature tighter blade-to-blade spacing, intentional mistuning, and thinner walls, which further increase costs for both new engine designs and Navy sustainment needs. These requirements increase the potential need for an ECM manufacturing solution.

In addition, advanced designs are challenging the limits of current manufacturing techniques. Sharper leading edges, thinner walls, exotic tip geometries, and more complex curvatures can improve the overall engine efficiency or stall margins, but are more expensive, time consuming, or impossible to manufacture with conventional techniques. New material systems are being developed, such as titanium aluminides, high entropy alloys, and refractory alloys, which often have improved mechanical properties or heat resistance, increasing the challenge for contact-based machining processes and furthering the need for non-contact electrochemical methods.

Finally, there is growing interest in near-net-shape processes, such as low-cost casting or metal additive manufacturing. In these cases, a secondary subtractive machining process is often necessary to improve final part tolerance and reduce surface roughness. To take advantage of the single-part nature of near net components, the subtractive manufacturing process needs the ability to access hard-to-reach areas, an area where ECM can excel.

The low forces and insensitivity to material mechanical properties makes ECM a promising manufacturing technique to address all of these concerns, but its adoption has been largely limited to high volume commercial applications. The primary barrier facing greater adoption of ECM is the up-front non-recurring engineering expense (NRE) and process development costs. ECM is inherently inaccurate but repeatable, requiring iterations of the tooling to achieve the necessary accuracy. This iterative process of electrode design and process parameter selection is largely based on intuition and has limited its use to a few specialized firms, which rely on the knowhow and experience of its personnel. In addition, the tooling can be damaged by short circuit conditions during the testing phase, which damage the electrode and workpiece, leading to a time-consuming re-manufacturing process.

Given these challenges, the United States Navy is seeking improvements to the electrochemical machining process which can:

- Reduce the upfront tooling and NRE expense associated with current ECM processes

- Yield cost and lead time reductions of > 25% for turbine engine components including fan, compressor and turbine blades, advanced casing treatments and combustor liners, when compared to current best practices
- Be used for next generation metal material systems and geometries, including nickel superalloys and high entropy alloys
- Promote the standardization of ECM procedures, accessibility to the machining method for lower production rates, and ECM workforce development

PHASE I: Demonstrate proof-of-concept manufacturing of the improved ECM process on a relevant material system (e.g., Ti64 or IN718). Identify major risks to the proposed solution through analysis and/or experimentation. Identify solutions to the major risks. Test the proposed solutions on a representative geometry.

PHASE II: Address the risks and challenges by modifying or improving the baseline manufacturing technique demonstrated in Phase I. Additional manufacturing demonstrations will be performed on representative propulsion engine components and materials. Demonstration components will be inspected to identify quality issues (e.g., metallurgy impacts, surface defects), geometric tolerances, and material removal rates. A cost model will be developed demonstrating a pathway towards 25+% cost reduction and identifying the total manufacturing process chain (i.e., proposed technique + pre- or post-processing steps), the capital equipment and NRE costs associated with the proposed technique, and the operating expenses of the proposed technique.

PHASE III DUAL USE APPLICATIONS: Create a full-scale component using the developed manufacturing technique which could be used for further performance evaluation including rig testing, spin pit testing, or flow testing. If successful, this technology would have wide application in commercial advanced manufacturing for a variety of products.

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KEYWORDS: Advanced manufacturing; electrochemical machining; compressor; turbine; jet engine; blisk; IBR; machining; surface finish

N23A-T020 TITLE: Scalable Production of Carbon-Based Composites from Sequestered Environmental Carbon

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy

OBJECTIVE: Develop a low-cost, energy efficient synthetic approach to producing carbon-based composites from environmental carbon resources.

DESCRIPTION: The objective of this STTR topic is to develop a low-cost, low-energy synthetic approach to producing carbonaceous materials to be used in carbon-based composites to advance defense materials for the warfighter. These materials include carbon fibers, carbon nanotubes, carbon nanofibers, graphene, and graphite. Carbonaceous materials are typically used as fillers in polymer-matrix composites and ceramic-matrix composites. There is growing interest in utilization in Li-ion batteries, capacitors, and high strength building materials. The proposed synthetic process will reduce the complexity and cost associated with utilizing environmental carbon resources to synthesis the carbonaceous material while maximizing yield and purity.

PHASE I: Define the specific carbonaceous material to be synthesized, utilizing environmental CO2. Define, develop, and perform initial laboratory assessment of the proposed synthetic process to validate the technical feasibility of the approach to producing the carbonaceous material. Perform analysis of the material and determine initial yield and purity.

PHASE II: Based on findings in Phase I, define and develop a concept to produce kilogram-scale quantities of carbonaceous material. Produce selected materials and determine the physical characteristics (size and shape) along with strength, thermal and electrical conductivities, impurities, and yield as a function of changes in synthetic conditions. From the analysis and characterization, determine the appropriate steps to maximize CO2 usage, minimize energy, and costs associated with the approach. Identify Navy operational platform applications that are likely to benefit the most from this technology. Conduct a demonstration of the process and technology.

PHASE III DUAL USE APPLICATIONS: Identify opportunities where carbonaceous materials can be utilized from an installations / building materials perspective that could benefit Naval and commercial facilities. Provide a cost-benefit analysis to show effects of utilizing CO2 on cost and production of material.

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KEYWORDS: carbon-based composites; carbon fibers; carbon nanotubes; carbon nanofibers; graphene; graphite; synthesis

N23A-T021 TITLE: Autonomous, Long-Duration, Directional Ambient Sound Sensor

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy
OBJECTIVE: Develop an autonomous, long-duration, directional ambient sound sensing system capable of being integrated into a variety of platforms including floats, gliders, and ocean observation buoys. The system should output soundscape-related information in a manner that is scaled to match platform communications bandwidth.

DESCRIPTION: Sound waves generated by natural (both abiotic and biotic) and anthropogenic sources convey information about both the source and the environment in which they travel. Underwater recordings of ambient sound have been previously used to estimate local weather (wind, rain), to identify the presence/absence of marine organisms, and, particularly when directional information is included, to characterize the undersea environment. These systems, however, have not found widespread usage in the near-real-time reporting systems that currently exist in ocean observing networks (e.g., systems of floats and gliders, observational buoy networks). This STTR topic seeks to develop a low power (~1 W), long duration (months to years) system that can be widely integrated into ocean observing networks. Successful solutions will include onboard processing to provide generalized soundscape information, including sound intensity levels as a function of frequency and direction (both horizontal and vertical), event detection, and scalable reporting options that can be matched to host platforms (e.g., low data rate satellite communications, moderate data rate cellular communications). The system should output soundscape-related information in a manner that is scaled to match platform communications bandwidth. Innovations are anticipated at both the sensing level, particularly for the directionality of ocean sound and its use in characterizing the ocean environment, and at the onboard processing level where the information content of ambient sound is efficiently and autonomously extracted from the raw data. The successful solution will be scalable to wide-region distributed sensing (e.g., 10’s to 100’s of sensors throughout a sea, or 1000’s of sensors distributed throughout the world’s oceans).

PHASE I: Develop an initial concept design that can accommodate various host platforms including floats, gliders, and observation buoys. The concept design should include sensing concept and configuration, mechanical packing, power consumption, communication interfaces, sensor (re)calibration methodology, algorithms to extract the information content of the ocean sound, and estimated data rate(s). Algorithms are expected to be tested on previously collected or simulated data (e.g., passive acoustic data held by the NOAA National Centers for Environmental Information).

PHASE II: Develop a prototype autonomous, long-duration, directional ambient sound sensor, integrate it into a host platform, and use real-world data to analyze its performance including sensitivity, self-noise, dynamic range, direction-resolving capability, power consumption, longevity, and sensitivity stability.

PHASE III DUAL USE APPLICATIONS: Demonstrate the use of a regional network of sensors (e.g., 10’s of systems) including deployment, data collection/communication, and data analysis (e.g., generalized soundscape information and event detection).

Naval applications of this system include the capability to validate and fine-tune ambient sound models and databases in operational environments, including real-time updates in the temporally and spatially varying ocean. Although the direct sensor output data will be unclassified, its use in direct coordination with Navy ambient sound models and databases may be CUI or classified.

Commercial application of this technology is anticipated to be tied to the blue economy, including the detection of protected species in areas of interest to commercial fishing and offshore wind technologies.

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KEYWORDS: Ambient Noise; Soundscape; Sonar; Autonomous; Ocean Observing; Environmental Sensing

N23A-T022 TITLE: Lightweight Mirrors for Microsatellites and Small Satellites

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Space Technology
OBJECTIVE: Develop innovative manufacturing methods to produce high-quality lightweight optical mirrors for use in space on microsatellites (microsats) and small satellites (smallsats), particularly at ultraviolet (UV) and extreme ultraviolet (EUV) wavelengths.

DESCRIPTION: The Navy seeks improvements in the manufacturing of lightweight optical mirrors to meet size and weight demands of compact optical systems designed for operation in space on the next generation of microsats being designed to study the ionosphere [Refs 1, 2] and other Navy applications. Availability of high-quality lightweight optics will allow for future mission growth. The Navy seeks to foster the development of affordable optical components and systems that could have broad application to space systems. Current mirror technology involves either fragile glass optics or metal or composite mirrors that have lower optical quality. Innovative substrate materials are sought with the ruggedness, mass, and material properties necessary to produce light weight high-quality optical elements. Innovative techniques are sought to polish and figure these substrates to yield the high optical quality reflective surfaces needed for the new class of remote sensing instruments.

Typical cube satellite (CubeSat) mirrors used in smallsats have been fabricated from special aluminum alloys that are hard enough to be polished with moderate difficulty. Their density is 2.7 g/cm3, leading to significant mass penalties. The example sizes range from a fixed flat mirror (3” x 3.5” by 0.080” thick) to a scanning mirror (2” X 3.5” by 0.375” thick). Improvements are sought in the density, stiffness, polishability, roughness, figure accuracy, and moment of inertia in the scanning case. Goals are figure accuracies of $\lambda/4$ at the working wavelength, scratch/dig of 60-40, rms roughness of < 1nm, Coefficient of Thermal Expansion (CTE) compatible with typical spacecraft materials (< 4ppm/K), low outgassing (CVC < 0.1% and TML < 1%), survival at temperatures of -50 – +60°C, and the ability to survive a NASA GEVS3 vibration specification and thermal test environment, all typical of the requirements imposed for flight on small spacecraft.

Technologies proposed should not contain hazardous or high outgassing materials and should be capable of being integrated into typical optical systems. It is desired that they be moderately (> 10-5 O-1/m) electrically and thermally conductive (> 10W/mK) to avoid developing static charge and thermal gradients in space. They should be durable and able to withstand normal optical component handling procedures. They should be delivered in an optically clean state and be robust enough to withstand precision cleaning and vacuum baking as part of normal spacecraft processing.

PHASE I: Demonstrate the feasibility of a concept for an innovative lightweight mirror technology meeting Navy needs for microsat optical systems in the ultraviolet/vacuum ultraviolet (UV/VUV). Demonstrate performance advantages over current technology by producing small (25mm or larger) flat sample mirrors that can be tested to Navy requirements. While exact mirror dimensions are not specified for Phase I, the awardee will establish that the concept can be scaled to sizes of 100 mm diameter or larger. Phase I technology is expected to focus on the small flat mirrors that are needed to fold optical systems into compact smallsat envelopes. The path to using this technology to produce curved mirrors should be defined.

Proposed mirror concepts should meet the following thresholds:

Deliverable Design Characteristics	**Value**
Mirror major dimension	25mm or larger

Mirror thickness	low, < 1/6 major dimension
Substrate density	< 1 g/cm^^{3}
Mirror flatness	< 1 wave
Mirror scratch-dig	60-40
Mirror roughness	< 1nm
Survival Temp range	-50 - +60°C
Reflective Coating	for UV or VUV
Vibration, shock, and Thermal	NASA GEVS3

PHASE II: Develop a Phase II prototype mirror of the 100 mm size class for evaluation. The prototype will be evaluated to determine its capability in meeting the performance goals defined in Phase II Statement of Work (SoW) and the Navy's need for lightweight flight mirrors. The prototype design should provide reflective areas no less than 90mm by 40mm (objective), and should show applicability to be utilized with various mirror geometries and spacecraft architectures. Deliver a minimum of five of these prototypes to the Navy for evaluation. Perform detailed analysis to ensure materials are rugged and appropriate for Navy application. Environmental, shock, and vibration analysis will be performed. Optical checks will include flatness, roughness, and reflectivity. Prototype concave mirrors of 25mm diameter and ~100mm Radius of Curvature (ROC) will be produced and evaluated.

PHASE III DUAL USE APPLICATIONS: Apply the knowledge gained in Phase II to build an advanced mirror, suitably configured for a smallsat application, including flight spares, and characterize its performance in the UV/VUV as defined by Navy requirements. Working with the Navy and applicable Industry partners, demonstrate application to a NAVY Space Test program (STP) flight test. Support the Navy for test and validation to certify and qualify the system for Navy use. Explore the potential to transfer the light weight mirror system to other military and commercial systems (NASA, University, Optics Industry).

Market research and analysis shall identify the most promising technology areas. Develop manufacturing plans to facilitate a smooth transition to the Navy.

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KEYWORDS: Lightweight space qualified mirrors, mirror technology, optical fabrication, spaceflight optics, spaceflight structures; microsatellites; small satellites; cube satellites

N23A-T023 TITLE: Integrated Optical Imaging of the Environment on Underwater Autonomous Vehicles

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy

OBJECTIVE: Advance integration of camera imagery collection and onboard processing for environmental sensing on low-power, long-duration oceanic gliders and/or profiling floats. The system should allow for two-way communication between the sensor and platform microcontrollers; and software architecture should be tunable to specific parameters, e.g., adaptive capability to turn on imagery collection at target locations or times (e.g., within a set distance from the surface or bottom). Onboard processing and file reduction should allow for near-realtime data delivery of select low-resolution imagery and/or analysis products from imagery via satellite comms (iridium, Starlink, etc.).

DESCRIPTION: Long-endurance profiling floats and gliders are critical components of today’s ocean environmental monitoring systems with standard sensor payloads sampling scalar fields (e.g., temperature, salinity, fluorescence). These platforms, which are available as off-the-shelf units or manufactured in house at academic institutions, can be modified to carry additional specialized sensors. Such efforts are often targeted to a specific science need, but are rarely fully integrated with the platform, and exist primarily as one-off prototypes. The field of underwater optical imaging has a long history with significant recent advances afforded by continued development of low-cost, high-performance sensors and computational capabilities for onboard processing [Ref 1]. Recent developments have included optical sensing packages with low-power and small space requirements making them suitable for integration on long-endurance platforms [Ref 2].

The Navy seeks a fully integrated, low-power optical imaging system on long-endurance (~6 month mission capability) profiling platforms. While all components—the platform, optical sensing packages, and compression/analysis software—are available in some form as commercial off-the-shelf systems; integrated systems that allow for real-time delivery of compressed information are in their infancy. Additionally, most optical imaging systems appropriate for use on small displacement vehicles target imaging of plankton [Ref 3]. This STTR topic seeks a design capable of imaging both the near-field (order 1 cm) and mid-field (order 1 m) of view, with camera sensors capable of resolving both millimeter- and meter-scale objects. The system can consider either passive or active imaging techniques optimized for the euphotic zone. Imaging should extend both below and above the surface with potential sensing targets: relative motion of marine snow and particulates, near-surface bubble concentration, above-surface environmental conditions (e.g., films, white-capping). Critically, the design must be integrated allowing for adaptive sampling with the sensor package and include onboard processing capable of providing near-realtime data delivery of select low-resolution imagery and/or analysis products from imagery via satellite comms (iridium, Starlink, etc.).

PHASE I: Identify hardware components that can meet the stated requirements. Develop a concept for onboard software, including analysis of bandwidth and data transfer constraints. Develop a design concept for the integrated optical imaging system. Analyze for strengths and weaknesses of the proposed design. Develop a design review to be conducted in Phase II.

PHASE II: Develop and test a prototype system. Complete an analysis of the performance of the system and report on the results. Conduct multi-stage testing allowing for redesign between tests with initial tests in a surrogate ocean environment (e.g., lake or tank), interim test in the ocean under controlled conditions (e.g., coastal bay), and final test in the field under a range of environmental conditions. Develop and test both hardware and software systems. The final prototype should include a fully integrated sensing package capable of adaptive sampling and delivery of data via satellite. Analyze and report on the strengths and weaknesses of the final design based on results of the field tests.

PHASE III DUAL USE APPLICATIONS: The developed technology has potential use in any DoD, civil, or commercial application that requires detailed information on the ocean environment as certain elements, like the presence of marine vegetation or surface slicks/films, are not easily sensed through other means. Field testing in Phase II will constrain the parameter space under which the system is operationally capable for the Navy. Other potential use sectors include the oil and gas industry (e.g., tracking of spills under ice), and state/federal marine life monitoring agencies (e.g., NOAA Fisheries Monitoring and Analysis Division).

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KEYWORDS: optical imaging, underwater autonomous vehicles, ocean gliders

N23A-T024 TITLE: Compact Condensers Enabled by Additive Manufacturing

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Microelectronics; Advanced Materials

OBJECTIVE: Develop novel, additively manufactured refrigerant to water condensers for use in electronic cooling systems.

DESCRIPTION: Cooling of high power electronics via refrigerant evaporation presents a significant opportunity to reduce the size, weight, and power (SWaP) consumed by thermal management systems. Recent advances have led to demonstration of compact microchannel evaporators with heat transfer coefficients in excess of 100 kW/m2^K and low pumping powers. Condensers are often the largest component in a two-phase cooling system. Commercial condensers are typically shell and tube designs with heat transfer coefficients less than 5000 W/m^2K. Military systems often use a secondary coolant loop to transport heat from condensers. For example, naval platforms use a freshwater cooling system, while air platforms have a polyalphaolefin (PAO) coolant loop. Recent progress in metal additive manufacturing has enabled the fabrication of air heat sinks and cold plates with complex flow geometries. Additive manufacturing also allows for thinner walls, reducing weight and thermal resistance. Most metal additive manufacturing technologies are based on powder processing, with a limited number of alloys commercially available. Process parameters can greatly affect the microstructure and mechanical properties of the resulting metallic heat exchanger, leading to concerns about long term durability. Heat transfer enhancement using internal structures embedded inside flow passages is commonly used to increase local convection heat transfer, but has been limited to simple structures by conventional manufacturing techniques. Additive manufacturing can enable more complex structures, but demonstrations to date have been largely limited to intuitive designs. Topology optimization has recently been applied to the design of additively manufactured cold plates, but the designs are limited to two-dimensional optimization due to computational complexity. New tools are needed to enable the full potential of additive manufacturing to realize optimal three-dimensional designs. This STTR topic seeks innovative condenser designs enabled by metal additive manufacturing for efficient cooling of electronics.

PHASE I: Design a compact, additively manufactured, metal heat exchanger for condensing a refrigerant with saturation temperatures below 35 °C (R134a preferred) using freshwater at 25 °C for heat rejection. Pressure drop on both the refrigerant and water side should be minimized to optimize efficiency. Verify feasibility using modeling and/or component demonstration. Perform rough manufacturing cost analysis. Develop a Phase II plan.

PHASE II: Demonstrate a prototype R134a condenser using the concept developed in Phase I. The prototype should be able to reject 50 kW of heat to a fresh water system at 25 °C. Evaluate the efficiency of the prototype under various electrical and cooling loads and temperatures. Performance data, including heat transfer and pressure drop, shall be collected at a variety of flow rates (both refrigerant and water), temperatures, and entrance qualities. Validate analytic models developed in Phase I and evaluate scalability of design.

PHASE III DUAL USE APPLICATIONS: Design and develop the next generation of compact, high efficiency condensers using the knowledge gained during Phases I and II. These heat exchangers must meet military unique requirements, e.g., shock and vibration. Advanced condensers developed here would be suitable for use in a variety of commercial applications, from hybrid vehicles to building air conditioning.

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KEYWORDS: thermal management; two-phase cooling; condenser; additive manufacturing; heat exchanger

N23A-T025 TITLE: Cloud Nowcasting Data/Model Fusion

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy

OBJECTIVE: Develop an algorithmic tool for the seamless assessment of previous, current and short term forecast (0-24 h) atmospheric cloud characteristics such as ceiling, thickness, and optical depth for single and multiple overlapping cloud fields using machine learning methods to combine satellite based environmental monitoring (SBEM) analysis information, ground based remote sensing, and numerical weather prediction model fields.

DESCRIPTION: Despite increasing complexity and accuracy of weather forecast models, tools for their use in diagnosing cloud and visibility characteristics are relatively unsophisticated. Many use cases assume a relatively static cloud field based on available satellite analysis data, climatological occurrence of cloud locations, or derived numerical weather prediction output (such as relative humidity fields). Using state of the art technology, this STTR topic seeks to bridge the gap between cloud analysis by satellite and forecasts from numerical modeling by using machine learning techniques and other data fusion capabilities to improve forecast uncertainty and cloud representation through a 24 hour forecast lead-time. Effort should focus on improved post processing of cloud characteristics in numerical modeling as well as techniques to seamlessly morph a true cloud analysis field from satellite into the predicted field. Implementation should take advantage of modern software strategies, including concise data presentation and intuitive user interface to display custom visualization of clouds from any 3 dimensional angle.

PHASE I: Determine and demonstrate the technical capability to smoothly transition observed satellite observations of cloud cover into simulated cloud (or meteorological variables interpreted as cloud) forecasts. Work should identify methodological details to preserve the physical structure of observed cloud visibility characteristics, aesthetics and ease of interpretation, and incorporation of probabilistic information for metrics of uncertainty and/or alternate future scenarios. Skill with respect to aviation needs should be enumerated (e.g., accuracy of cloud ceilings, error in horizontal and vertical positioning, treatment of overlapping cloud layers) given validating data from ground lidar or other full atmosphere representation. Develop a final summary report, including literature review and overall conclusions/recommendations, to be presented at the end of this Phase. Develop a Phase II plan.

PHASE II: Expanded technical development and validation of a robust prototype system of seamless historical, current, and future cloud state. Effort should be focused on 1) maturing complex machine learning algorithms that improve forecast representation of clouds given observed satellite cloud state (including advective schemes such as optical flow, clustering of cloud types, and texture analyses), 2) adding additional data sources and expanded spatial domain to prove application to any global location, and 3) iterating on accuracy and ease of user interface in display of cloud fields. Given the need to add many different satellite platforms and forecast model data, substantial subtasks on developing generic data reader capabilities and automated metadata generation and labeling are anticipated. While the code itself may need nominal high performance computing to run, output of prototype algorithm should be capable of being visualized on a standard laptop or cellphone with modest data bandwidth (such as by tiling). It is anticipated that the prototype data output and software package will be compatible with running from open source python data analysis libraries at the conclusion of Phase II efforts. Delivery of a prototype software package and final verification report is expected at the end of this Phase.

PHASE III DUAL USE APPLICATIONS: This development will result in valuable knowledge and technology advances for the entire meteorological analysis and forecasting community, as well as downstream applications. Further follow-on Phase II efforts include expansion of observational and remote sensing datasets used to generate and validate the algorithmic tool, software refinements and hardening based on real-world operational constraints (such as data latency and drop outs, quality issues, etc.), and further tests of blending code to similar meteorological variables (such as atmospheric water constituents). DoD, civil, and private aviation will particularly benefit by having a state-of-the-art product aimed at understanding cloud visibility evolution at all stages of flight operations, from take-off through ferry and landing. Naval applications will particularly benefit by the significant increase in specific environmental data and available at any point where the Naval aircraft operations can occur. Other civil and commercial applications will benefit from enhanced data streams and software implementations for broad aviation and visibility applications, improved predictability in weather forecasts, and increased cross-over between civil and commercial satellite remote sensing activities. This effort has the potential to fill a data gap in all aspects of meteorological analysis as well as provide a foundation for additional data fusion opportunities.

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KEYWORDS: meteorology; weather; clouds; visibility; nowcasting; forecasting; numerical weather prediction; Satellite Based Environmental Monitoring; SBEM; satellite; remote sensing; data fusion; machine learning; optical flow; visualization; metadata; aviation

N23A-T026 TITLE: Development of Finite-Rate Ablation Toolset for Hypersonic Vehicles

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Hypersonics; Nuclear

OBJECTIVE: Formulate, implement, and validate finite-rate ablation models for hypersonic boost-glide vehicle thermal protection systems (TPS) such as 2D and 3D carbon-carbon (C/C) for accurate prediction of vehicle shape change, temperature distributions, and ablated species.

DESCRIPTION: Boost-glide vehicles primarily rely on ablating TPS. Unlike strategic ballistic missiles, boost-glide weapons operate for a long duration in a range of altitudes and velocities where the rates of energy excitation, chemical reactions, ionization, and gas-surface interactions are comparable to the rate of fluid motion. This implies that the accuracy of legacy modeling approaches that assume equilibrium thermo-chemistry and equilibrium ablation are questionable for such systems. Recent numerical studies of graphite ablation at boost-glide relevant flight conditions have shown that equilibrium ablation models (i.e., B’ method) significantly over-predict nose-tip ablation compared to finite-rate ablation models [Ref 1].

Over the last decade, significant improvements have been made in the understanding and prediction of finite-rate processes in hypersonic flows by using ab initio quantum chemistry methods to generate potential energy surfaces (PES) for molecular interactions [Ref 1]. The PES can be used for the direct simulation of collisions between air species to obtain data for relaxation and reaction rates at specified conditions [Ref 2]. These data have enabled improved finite-rate chemistry models for computational fluid dynamics (CFD) simulations that accurately account for the vibrational energy state of the air species in the dissociation process [Ref 3]. Over the same time period, improvements have been made in the development of finite-rate carbon oxidation models based on molecular beam experiments of high-velocity O, and O2 species impacting high-temperature carbon material [Ref 4]. Such experiments enable the characterization of individual reactions and rate parameters as opposed to plasma wind tunnels experiments that measure the combined outcome of many reactions such that multiple combinations of parameters can be used to match the measured recession rate. Different finite-rate ablation models that produce comparable ablation rates can predict large difference in the ablation species such as CO, CO2, and CN. Very recently, molecular beam experiments that included the interaction with N and N2 species have provided the data needed for the development of construction of air-carbon ablation models relevant to hypersonic flight that include nitration in addition to oxidation [Ref 5].

Recent progress in the development of finite-rate carbon ablation models is encouraging, but these models need to be validated under a range of relevant hypersonic conditions and geometries for simple and relevant materials such as 2D and 3D C/C. This is needed as current molecular beam data has been obtained on highly oriented pyrolytic graphite (HOPG) and vitreous carbon as experimental models for the fibers and matrix, respectively, of C/C.

It is also imperative to implement the new finite-rate ablation models in fully coupled CFD / material response codes to predict the TPS shape change, temperature distributions and ablated species. In addition, the assessment of TPS thermo-structural properties, surface roughness, and damage requires the simulation of the material microstructure.

PHASE I: Formulate and implement finite-rate air-carbon ablation models in coupled CFD material response. Perform comparison against existing experimental data for simple materials such as HOPG and vitreous carbon. Quantities of interest include ablation rates (shape change), surface temperature, and ablated species. Criteria for success include the successful model implementation in material response code and validation.

PHASE II: Refine the finite-rate ablation models and their implementation for relevant materials such as 2D and 3D C/C. The model refinement could include fundamental measurements on C/C to understanding the effect of the material microstructure on the reaction rates and parameters. Validation under a range of relevant hypersonic flow conditions in an arc-jet and or inductively coupled plasma torch (ICP) for nose-tip, leading-edge, and acreage are required to assess the accuracy of the ablation models.

PHASE III DUAL USE APPLICATIONS: Improve the models and efficiency of the coupled hypersonic CFD / ablation toolset for prediction of shape change on complex geometries. The ablation toolset will ultimately be demonstrated on a relevant Navy weapons geometry via ground and/or flight test once a sufficient TRL is achieved.

In the near term, this technology is geared toward military applications, but the methodologies for ablation model development and ablation toolset can be commercialized for commercial space vehicles using C/C TPS. Additional development for carbon-phenolic materials are also possible to expand the range of applications.

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KEYWORDS: Ablation; carbon-carbon; finite-rate; boost-glide; molecular-beam; oxidation; nitration

N23A-T027 TITLE: Digital Sidekick for Submarine Watchstander Augmentation

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy; Integrated Network Systems-of-Systems

OBJECTIVE: Develop a haptic alert system (Digital Sidekick for Submarine Watchstander) to substantially accelerate information delivery timelines for critical alerts, which can be delayed or completely missed due to information overload.

DESCRIPTION: Information overload is a critical factor negatively impacting the effectiveness of submarine watchstanders. Wrist or body worn haptic devices and haptic notifications have been shown to substantially shorten response times by immediately focusing attention on critical information or alerts being delivered by an artificial intelligence/machine learning (AI/ML) process designed to aid a watchstander. These devices are not currently deployed for submarine watchstations, Creating a process for accelerating delivery of critical information and alerts for submarine watchstanders can increase efficacy of numerous watchstations in time critical scenarios that will increase platform lethality, overall operational effectiveness, and platform survivability. This STTR topic seeks to deliver a haptic alert system that can be configured for a particular watchstation or individual to immediately alert and orient the person to critical information that requires urgent action. The principal objective will be to offer information delivery methods that cannot be missed in the most stressful scenarios, enabling a clear and focused response to the alert being provided. Key attributes for the project will include certainty of notification and watchstander awareness and understanding of information delivered which will result in measurable time savings for the required response. Ideal measure of effectiveness would include no missed alerts and substantially accelerated response times compared to scenarios without a haptic alert system.

PHASE I: Identify technical design options to enable haptic delivery of alerts for a variety of submarine watchstations (e.g., sonar, electronic warfare, roving watchstanders, etc.). Technical solutions should address certainty of alert, durability and resiliency of devices and systems being utilized to provide the alert, and methods to reduce false alerts. Establish the feasibility of the concepts. Work to identify suitable testing locations for Phase II.

PHASE II: Develop and deploy prototypes to suitable testing locations, including schoolhouse and platforms, to evaluate and determine impact of the prototype haptic critical alert and information delivery system(s). Work with users to define the most effective applications and use cases for most impactful technical applications for information delivery augmentation.

PHASE III DUAL USE APPLICATIONS: The products and capabilities developed under this topic will transition to submarine watchstanders that can benefit most from the new information delivery approach. It is envisioned that multiple approaches will be viable with ADNS/SWFTS, Sonar, EW, Engineering Space and Forward Roving watchstanders obtaining clear benefit from improved information delivery and receiving critical alerts immediately through haptic notification. A dual use commercial application could also be pursued with similar haptic alert applications in a variety of scenarios involving commercial power generation or mechanical fabrication facilities. Due to the routinely quiet and vibration free environment on a submarine, it is uniquely suited to benefitting from haptic information delivery technology, but some stationary or low noise/vibration monitoring activities in the commercial sector could also potentially benefit from this technical approach.

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KEYWORDS: Haptic; Perception; Multisensory; Feedback; Information Overload; Critical Alert; Interaction; Digital Sidekick; Watchstander Augmentation; Kinesthetic Feedback; Wearable Devices

N23A-T028 TITLE: Broadband, High Power, Low Loss N-polar GaN Radio Frequency (RF) Switches

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): FutureG; Microelectronics; Integrated Network Systems-of-Systems

OBJECTIVE: Maximize radio frequency (RF) Switch performance in Nitrogen-polar (N-polar) Gallium Nitride (GaN) based on a high electron mobility transistor (HEMT) epitaxial layer structure capable of 4 W/mm power density.

DESCRIPTION: RF switches are used in virtually all wireless systems. Losses or distortion in front-end switches directly impacts final system performance metrics. Traditional solid state RF switch performance is limited by the underlying switch transistor or diode device’s figures of merit including switch cutoff frequency, linear and saturation current density, and breakdown voltage. New switch device technologies including MEMS and phase change materials have shown higher performance but have drawbacks including lacking the switch cycle endurance needed for many applications, the difficulty of integration that adds losses which can negate some of their performance advantages, and for MEMs a greater vibration/shock susceptibility.

N-polar GaN has recently shown record solid-state transistor switch performance metrics including a 1.7 THz switch cutoff frequency, and a straightforward path exists for monolithic integration of N-polar GaN power amplifiers (PAs) which are expected to also show record performance. Integration of an RF switch, power amplifier, and low noise amplifier (LNA) will enable low cost transceiver technology for applications addressing microwave to mm-wave systems. Recent results reported for N-polar GaN HEMT on Sapphire point to a very low-cost manufacturing for an integrated RF switch with a PA, and complete transceivers.

Switch circuit application examples and metrics that can be pursued in this STTR topic:

Ultra-broadband medium power low-loss switch: DC-100 GHz SPDT switch with > 2W 1dB compression point, > 10W off-state power handling, < 2 dB loss, 20 dB isolation

Low-loss, high linearity, Ka-band antenna tuning switch: 26.5-40 GHz SP4T switch with 50 dBm IP3

High-power S-Ku band switch: 2-18 GHz SPDT switch with > 10W P1dB

Alternate switch applications offered by proposers will be considered.

PHASE I: Fabricate, characterize, and model switch device cells needed for the range of designs. Design and simulate switch circuits, using an epitaxy which supports power devices with 4W/mm and 25% power-added efficiency (PAE) at W-band. Characterize the switch device cell for loss, isolation, linearity, and power handling. Report on switch circuit design and simulation including loss, isolation, linearity and harmonic performance, and power handling for different applications.

PHASE II: Refine models and fabricate switch circuits. Characterize switch circuits against the metrics and fabricate optimized designs based on specific applications proposed for Phase II. Implement fabrication process variations to correlate process parameters on field-effect transistor (FET) performance in a fab process flow suitable for integration with N-polar GaN PAs.

PHASE III DUAL USE APPLICATIONS: Demonstrate an integrated RF switch with PA in N-polar GaN, and alternatively a complete transceiver including RF switch, PA, and LNA relevant to the metrics in the above Description and the Phase I goals.

Dual use applications are expected to include commercial SATCOM, terrestrial backhaul communications for 6G and higher, Wi-Fi 6, and next generation wireless networks.

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KEYWORDS: GaN; Gallium Nitride; High Electron Mobility Transistor; HEMT; Nitrogen Polar; RF Switch

N23A-T029 TITLE: Non-Intrusive Aerodynamic State Sensing for Hypersonic Flight Control

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Hypersonics; Microelectronics

OBJECTIVE: We will develop the flow theory, measurement technology, and estimation algorithms to enable non-intrusive aerodynamic state sensing for hypersonic flight control. The flow theory will describe measurable flow phenomena and their correlation to a weapon's aerodynamic state. The measurement technology will sense the flow phenomena and produce correlated signals without devices that protrude into the flow around the weapon. The estimation algorithms will process the signal data to produce accurate and precise estimates of the weapon's aerodynamic state. Collectively, the flow theory, measurement technology and estimation algorithms will be the foundation of a non-intrusive air data system that can operate in sustained hypersonic flight conditions. The system will produce aerodynamic state estimates at a rate sufficient for flight control.

DESCRIPTION: Hypersonic flight conditions drive phenomena, e.g., chemical dissociation, material ablation, etc., that are generally not encountered in other flight regimes. Recent hypersonic flight experiments seek to understand phenomena such as boundary layer transition and its impact on heat transfer [Ref 1]. Ground-based hypersonic research has spurred successful investigations for non-intrusive flow measurement in a wind tunnel [Refs 2, 3]. Researchers have long recognized air data's critical importance to controlled hypersonic flight. Driven by the promise of hypersonic flight sustained by air breathing propulsion, researchers investigated air data systems needed for highly coupled flight and propulsion control systems [Ref 4]. Despite the lack of an air-breathing engine, successful hypersonic flights with the X-15 rocket plane provided useful information on air data challenges. Even a sensor with 1% accuracy is not sufficient for control under the extreme pressures and temperatures associated with hypersonic flight. Researchers investigated a broad array of technologies ranging from pressure transducers to gas fluorescence with laser excitation as they worked to solve the air data problem for hypersonic flight [Ref 5]. Thus far, researchers have not identified a single technology capable of producing sufficient accuracy, precision, and bandwidth across the entire flight envelope of a hypersonic weapon, especially for weapons that cover subsonic, supersonic, and hypersonic conditions in a single flight. This raises the importance of state estimation algorithms that will need to fuse data from varying sensors over a broad range of conditions and aerodynamic phenomena. As flow diagnostic science and technology advanced for hypersonic wind tunnel experiments, researchers began to investigate these approaches for flight experiments. Researchers investigated electron beam fluorescence as a tool for non-intrusive flow diagnostics of the boundary layer in a hypersonic vehicle [Ref 6]. Researchers have also proposed using Raleigh Lidar to measure upstream density in concert with electron beam fluorescence to measure density and temperature of gas species within the boundary layer [Ref 7]. Given the potential and historical significance of using surface pressure measurements to estimate a vehicle's aerodynamic state, researchers developed algorithms and an array of flush-mounted pressure sensors to estimate the aerodynamic state of an uncontrolled hypersonic flight experiment [Refs 8, 9]. A more recent flow visualization method that researchers have proven in the wind tunnel is Femtosecond Laser Electronic Excitation Tagging (FLEET), and they investigated FLEET as a measurement solution for a hypersonic air data system [Ref 10]. Researchers have demonstrated flow-imaging rates of 100 kHz using FLEET [Ref 11]. Given the extremely high speed of hypersonic vehicles, one might reasonable consider using only the inertial velocity vector to estimate the aerodynamic state. However, hypersonic vehicles go through large speed ranges as they accelerate to hypersonic speeds and decelerate while maneuvering. The difference between Earth-relative and Air-relative velocities can become non-trivial, and this large flight envelope ultimately requires hypersonic air data systems that also work below hypersonic speeds. Researchers addressed this challenge by investigating air data solutions built primarily on more complex algorithms rather than more complex sensors [Ref 12].

Continuing these scientific and technological developments, the objective is to develop the flow theory, measurement technology and estimation algorithms to enable non-intrusive aerodynamic state sensing for hypersonic flight control. Researchers have investigated and demonstrated numerous methods for hypersonic flow visualization in a wind tunnel, and they have made some headway towards translated these methods to flight vehicles. Successful performers will prototype a flight-representative, non-intrusive air data system with performance sufficient for flight control from subsonic through hypersonic conditions. Detailed modeling and analysis of the air data system, rigorous testing and model validation of subcomponents are critical first steps. Key system parameters and outputs are:

- Air data measurement accuracy & precision
- Air data measurement rate
- Air data measurement time delay
- Air speed
- Aerodynamic angles
- Air density and temperature
- Robustness to hypersonic conditions, e.g., ablation, temperature, plasma, shocks, etc.
- Robustness to weather and environmental conditions
- Measurement range from subsonic through hypersonic

Proposers must explicitly answer all of the Heilmeier questions to be considered for an award.

PHASE I: The performer will work with Government and Industrial partners to establish a range of flight conditions for aerodynamic state sensing. Once the flight envelope is established, the performer will focus on evaluating current air data technology as well as investigating potential new approaches. New approaches may be driven by recent advancements in measurement techniques for flow diagnostics, modelling techniques for flow/structure interaction, high temperature materials for sensors, or any other technology that can produce a signal with a reliable correlation to a vehicle's aerodynamic state.

The performer will deliver the theory, modelling, and analysis of an air data system that functions from subsonic to hypersonic flight conditions. The theory will include a detailed explanation of the working principles behind the system, from flow dynamics to sensor dynamics. Modelling will include first order dynamics of the vehicle flow and sensors as well as algorithms for estimating a vehicle's aerodynamic state. Analysis will include simulation results and predicted performance of the system based on the first order models. These deliverables will be in addition to the Navy's standard Phase I deliverables listed in a contract award. A milestone for continuing to Phase II will be conceptual design calculations indicating that the proposed solution meets the established performance criteria.

PHASE II: The performer will refine the theory of operation, increase model fidelity, and conduct higher order analysis to support the detailed air data system design. The performer will complete the engineering and detailed design for the concept developed in Phase I. Design details include physical and electrical interfaces, materials & devices, fabrication & assembly methods, signal conditioning electronics, embedded software, processors, power supply, cooling, etc. The analytical model developed in Phase I will be updated to include component models with sufficient complexity to predict the prototype system's performance. The detailed explanation of the working principles behind the system will be updated to include implementation considerations such as quantization, sensor noise, sampling delays, filter dynamics, data fusion, etc. The model will be used to justify component requirements and predict the prototype system's accuracy. The Phase II base scope will also produce a detailed test plan to validate both the system and the dynamic model. The test plan will cover everything from component level testing, ground testing, and flight testing. Ideally, flight testing would include hypersonic flight, but testing may be limited to supersonic flight. Test and validation for critical components will be included in the Phase II base period. Milestones required for the Phase II Option, if exercised, will be a detailed prototype design, validated test results for critical components, a detailed system model predicting acceptable performance, and an approved test plan. The Phase II Option will continue with any necessary component testing and fabrication of the prototype air data system. The milestone required for any Subsequent Phase II funding will be successful ground testing to demonstrate agreement between predicted and measured sensor dynamics. Subsequent Phase II awards will complete the test plan through flight test.

PHASE III DUAL USE APPLICATIONS: Phase III will consist of four parts:
Phase IIIa will refine the prototype design to ensure compliance with production requirements for vibration, shock, electromagnet interference, security, electrical & mechanical interfaces, etc. Three serialized production representative air data systems will be produced in collaboration with an airframe manufacturer. Calibration data will be collected and archived for all of the systems. System Serial Number 0 (SN0) will be subjected to environmental testing necessary to qualify for flight.
Two milestones required for Phase IIIb funding are acceptable calibration data for all sensors and environmental test data to demonstrate that the production design meets requirements. Phase IIIb will integrate the system SN1 into a supersonic air vehicle in collaboration with an airframe manufacturer. System SN2 will be maintained as a spare. Flight test instrumentation will be installed to gather high rate sensor data as well as truth data from conventional sensors. A ground test plan will be developed, and ground testing will be conducted to ensure proper mechanical and electrical interfacing with the host vehicle as well as functionality of the air data system and flight-test instrumentation. The performer will develop a Flight Test Plan (FTP) for testing and evaluating the system. The FTP will include prescribed maneuvers, predicted responses, and pass/fail criteria for each test case. Highly dynamic maneuvers and variable atmospheric conditions will be included. Where possible, the FTP will include experiments to simulate phenomena present in hypersonic flight, e.g., ablative particulates, high temperatures, chemical dissociation, etc. The FTP will also specify equipment, team members and training requirements. A Flight Test Readiness Review (FTRR) will be conducted to get approval to execute the FTP.

The milestone required for Phase IIIc funding is a successful FTRR. Phase IIIc will execute flight tests following the FTP. The flight experiments should produce data suitable for documenting the air data system’s accuracy and precision in an operational environment. The performer will assess the results and estimate the impact of hypersonic flight conditions on the system performance. The performer will draft a Flight Test Plan for conducting a hypersonic flight test of the air data system.

The two milestones required for Phase IIId funding will be successful supersonic flight experiments with simulated hypersonic flight phenomena and an approved FTP for a hypersonic flight test. Phase IIId will execute the hypersonic FTP. The FTP will include vehicle integration, flight test instrumentation, telemetry, ground testing, training, and execution of the flight experiment. The milestone for a successful Phase IIId will be hypersonic flight data demonstrating the efficacy of the air data system as a flight control sensor for precise, accurate, and high rate measurements of a hypersonic vehicle’s aerodynamic state.

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KEYWORDS: Hypersonic flight; flight control; air data; aerodynamic state estimation; conformal sensors; high temperature sensors; in situ hypersonic flow measurement