ONR Announcement N0001425SF002
ARO Announcement W911NF25S0004
AFOSR Announcement NOFOAFRLAFOSR20250002

NOTICE OF FUNDING OPPORTUNITY (NOFO)

Fiscal Year (FY) 2026 Department of Defense Multidisciplinary Research Program of the University Research Initiative (MURI)

Deadlines

White Paper Inquiries and Questions
18 April 2025

White Papers must be received no later than
02 May 2025 at 5:00 PM Eastern Time

Application Inquiries and Questions
22 August 2025

Applications must be received no later than
05 September 2025 at 5:00 PM Eastern Time

SPECIAL NOTE (1): Applications must be 'VALIDATED' by Grants.gov by the application deadline, which can take up to 48 hours after successful submission. See Section II.D.6.d.i. Timely Receipt Requirements and Proof of Timely Submission. It is strongly recommended that applications be submitted at least 2 business days ahead of the stated deadline.

SPECIAL NOTE (2): For ONR submissions: FedConnect is only used for white paper submissions. Do NOT use the FedConnect message center to submit questions or responses to this announcement. The message center is not monitored and your correspondence will not be received or responded to. Please contact the appropriate individual listed in Section A.9 Agency Contact Information for questions, and follow the FedConnect ReadySetGo guide for instructions on submitting a white paper response.

Contents

Overview of the Research Opportunity

The Department of Defense (DoD) Multidisciplinary University Research Initiative (MURI), one element of the University Research Initiatives (URI), is sponsored by the DoD research offices. Those offices include the Office of Naval Research (ONR), the Army Research Office (ARO), and the Air Force Office of Scientific Research (AFOSR) (hereafter collectively referred to as "DoD agencies" or “DoD”).

This publication constitutes a Notice of Funding Opportunity (NOFO) as contemplated in the Department of Defense Grants and Agreements regulations (DoDGARS) 32 CFR 22.315(a). The DoD agencies reserve the right to fund all, some, or none of the proposals received under this NOFO. The DoD agencies provide no funding for direct reimbursement of proposal development costs. Technical and budget proposals (or any other material) submitted in response to this NOFO will not be returned. It is the policy of the DoD agencies to treat all white papers and proposals submitted under this NOFO as sensitive competitive information and to disclose their contents only for the purposes of evaluation.

Hyperlinks have been embedded within this document and appear as underlined, blue-colored words. The reader may “jump” to the linked section by clicking the hyperlink.

A formal Request for Proposals (RFP), solicitation, and/or additional information regarding this announcement will not be issued.

DoD's MURI program addresses high-risk basic research and attempts to understand or achieve something that has never been done before. The program was initiated 40 years ago and it has regularly produced significant scientific breakthroughs with far reaching consequences to the fields of science, economic growth, and revolutionary new military technologies. Key to the program’s success is the close management of the MURI projects by Service Program Officers and their active role in providing research guidance.

Awards will take the form of grants. FOR ARO SUBMISSIONS ONLY, awards will take the form of grants and/or cooperative agreements. Any assistance instrument awarded under this announcement will be governed by the award terms and conditions that conform to DoD’s implementation of the Office of Management and Budget (OMB) circulars applicable to financial assistance. Terms and conditions will reflect DoD implementation of OMB guidance in 2 CFR Part 200, “Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards.”

Please note the following important items:

- Applicants should be alert for any amendments that may modify the announcement. Amendments to the original NOFO will be posted to the Grants.gov webpage: https://www.grants.gov/
- A project abstract is required with the application and must be publicly releasable as specified in Section D.1.c.b).ii.
- Responses to the Certifications and Representations indicated in Section H.1. of this NOFO are required with the application.
- The notice that advisors external to the U.S. government may be used as subject-matter-expert technical consultants in the evaluation of the proposals after signing non-disclosure statements is contained in Section F.3.c..

The complete list of topics is below. See Section I. Other Information for topic descriptions and more information.

AFOSR

Topic 1:	Characterization and Modeling of the Mesosphere and Lower Thermosphere
Topic 2:	Ethical Constructs and Adaptive Learning Systems
Topic 3:	Structured Light for High Field, High Intensity Laser-Matter Interactions
Topic 4:	Optics with Dynamically Reconfigureable Arrays of Molecules and Atoms (OhDRAMA)
Topic 5:	2D/3D Heterostructures via Remote Epitaxy

ARO

Topic 6:	Fungalphabet: Deciphering the Hidden Language of Fungal Networks for Environmental Intelligence
Topic 7:	Evolving Chemistry and Biology to Degrade Polymers with Stable Chemical Bonds
Topic 8:	Space-time Metamaterials for Multi-dimensional Wave Transformation
Topic 9:	Altermagnetic Topology
Topic 10:	Ontology Engineering for Machine Learning in Open-ended Sensor, Model, User Systems
Topic 11:	Entanglement Engineering with Holographic Duality
Topic 12:	Curved Electromagnetic Propagation
Topic 13:	Optimized Photonic Inference Systems

ONR

Topic 14:	Evaluation and Monitoring of Large-Scale Generative AI
Topic 15:	Brain-inspired Large Neural Models for Intelligent Robots
Topic 16:	Reading between the lines: Connecting Deep Ocean Currents & Bedform Morphology
Topic 17:	Impacts of Aerosol Injection, Evolution, and Deposition on 3D Radiative Balance
Topic 18:	Interfacial Thermal Energy Transduction
Topic 19:	Inherent stability in hybrid metal halide perovskite semiconductors through understanding of in situ electrochemistry

Topic 20: Visual Perception and Attention for Real-Virtual Hybrid Environments

Topic 21: Continuous Improvement and Assessment to Achieve Autonomous Skilled Performance

Topic 22: Gas/Material Interactions for Ultra-high-temperature Materials in Hypersonic Flows

A. Basic Information

1. Federal Agency Name

Office of Naval Research
One Liberty Center
875 N. Randolph Street
Arlington, VA 22203-1995

Army Research Office
800 Park Office Drive
Research Triangle Park, NC 27709

Air Force Office of Scientific Research
875 North Randolph Street
Arlington, VA 22203

2. Funding Opportunity Title

Fiscal Year (FY) 2026 Department of Defense Multidisciplinary Research Program of the University Research Initiative

3. Announcement Type

Initial Announcement

4. Funding Opportunity Number

ONR: N0001425SF002
ARO: W911NF25S0004
AFOSR: NOFOAFRLAFOSR2025002

5. Assistance Listing Number

ONR: 12.300
ARO: 12.431
AFOSR: 12.800

6. Funding Details

a. Funded Amount and Period of Performance

The total amount of funding for the five years available for grants resulting from this MURI NOFO is estimated to be approximately $170 million dollars pending out-year appropriations. MURI awards are contingent on availability of funds, the specific topic, and the scope of the proposed work. Typical annual funding per grant is up to $1.5M. The amount of the award and the number of supported researchers should generally not exceed the limit specified for the individual topics in Section I.1.

It is strongly recommended that Applicants communicate with the Research Topic Chiefs listed with the topic descriptions in Section I.1. regarding these issues before the submission of formal proposals. Depending on the results of the proposal evaluation, there is no guarantee that any of the proposals submitted in response to a particular topic will be recommended for funding. On the other hand, more than one proposal may be recommended for funding for a particular topic.

7. Key Dates

Anticipated Schedule of Events *		
Event	**Date**	**Time (Local Eastern Time)**
Questions Regarding Eligibility and Technical Requirements **	18 April 2025	
White Papers Due (not required but strongly recommended)	2 May 2025	5:00 PM Eastern Time
Notifications of Initial Evaluations of White Papers*	13 June 2025	
Questions for Grants Officer Regarding Proposal Submission**	22 August 2025	5:00 PM Eastern Time
Proposals or Invited Proposals Due	5 September 2025	5:00 PM Eastern Time
Notification of Selection for Award *	January 2026	
Start Date of Grant*	1 May 2026	

*These dates are estimates as of the date of this announcement.
**Questions submitted after the Q&A deadline may not be answered.

IMPORTANT NOTE: White Papers are OPTIONAL but strongly recommended

8. Executive Summary

Since its inception in 1985, the Department's MURI program has funded teams of investigators with the hope that collective insights from multiple disciplines could facilitate the cutting-edge basic research required to address the Department's unique problem sets. The MURI program complements

the Department's single-investigator basic research grants and aims to make contributions to current and future needs of both the DoD and the larger scientific ecosystem.

9. Agency Contact Information

All UNCLASSIFIED communications shall be submitted via e-mail to the Technical Point of Contact (POC) with a copy to the designated Business POC, as designated below.

Comments or questions submitted should be concise and to the point, eliminating any unnecessary verbiage. In addition, the relevant part and paragraph of the Funding Opportunity Announcement NOFO) should be referenced. Questions submitted within 2 weeks prior to a submission deadline may not be answered, and the due date for submission of the white paper and/or full proposal will not be extended.

One or more Research Topic Chiefs are identified for each SPECIFIC MURI TOPIC. Questions of a technical nature on a specific topic shall be directed to one of the Research Topic Chiefs identified in Section I.1. entitled "TOPIC DESCRIPTIONS" of this NOFO.

NOTE: **DO NOT SUBMIT QUESTIONS VIA THE FEDCONNECT MESSAGE CENTER.** For questions, send an email directly to the appropriate point of contact listed below.

- **Questions of a policy nature shall be directed as specified below:**

MURI Program Points of Contact:

Office of Naval Research: Dr. Amanda Netburn
Email: Amanda.N.Netburn.civ@us.navy.mil

Army Research Office: Dr. Sue Kase
Email: usarmy.rtp.devcom-arl.mbx.aro-muri@army.mil

Air Force Office of Scientific Research: Ms. Katie Wisecarver
Email: afosr.rtb.muri@us.af.mil

- **Questions of a business nature should be submitted to:**

Veronica Lacey
OFFICE OF NAVAL RESEARCH
Email: veronica.y.lacey.civ@us.navy.mil

Ramila Century
USARMY ACC
Email: ramila.century.civ@army.mil

Jorge Gallegos
AIR FORCE MATERIEL COMMAND, AIR FORCE RESEARCH LABORATORY, CONTRACTING OFFICE (AFMC/AFRL RBKR)

Email: jorge.gallegos@us.af.mil

B. Eligibility

1. Eligibility for Competition

Proposals for supplementation of existing projects **are not eligible** to compete with applicants for new Federal awards under this NOFO.

2. Eligible Applicants

This MURI competition is open only to, and proposals are to be submitted only by, U.S. institutions of higher education (universities) with degree-granting programs in science and/or engineering, including DoD institutions of higher education. To the extent that it is part of a U.S. institution of higher education and is not designated as a Federally Funded Research and Development Center (FFRDC), a University Affiliated Research Center (UARC) is eligible to submit a proposal to this MURI competition and/or receive MURI funds. Ineligible organizations (e.g., industry, DoD laboratories, FFRDCs, and foreign entities) may collaborate on the research but may not receive MURI funds directly or via subaward.

To assess risk posed by Applicants, we review your application, proposal, and Office of Management and Budget (OMB) designated repositories of government-wide public and non-public data, including comments you have made, as required by 41 U.S.C. 2313 and described in 2 CFR 200.206 and 32 CFR 22.410 to confirm you are qualified, responsible, and eligible to receive an award.

When additional funding for an ineligible organization is necessary to make the proposed collaboration possible, such funds may be identified via a separate proposal from that organization. This supplemental proposal shall be attached to the primary MURI proposal and will be evaluated in accordance with the MURI review criteria by the responsible Research Topic Chief. If approved, the supplemental proposal may be funded using non-MURI or non-Government funds.

Disclosures of current and pending support made in this application may render an applicant ineligible for funding. Prior to award and throughout the period of performance, DoD may continue to request updated continuing and pending support information, which will be reviewed and may result in discontinuation of funding.

Limitations on Number of Applications – There is no limitation on the number of applications an applicant (organization) may submit under the announcement.

3. Contracted Fundamental Research

With regard to any restrictions on the conduct or outcome of work funded under this NOFO, ONR will follow the guidance on and definition of “contracted fundamental research” as

provided in the Under Secretary of Defense (Acquisition, Technology and Logistics) Memorandum of 24 May 2010. The memorandum can be found at https://www.acq.osd.mil/dpap/dars/pgi/docs/2012-D054%20Tab%20D%20OUSD%20(ATL)%20memorandum%20dated%20May%2024%202010.pdf.

As defined therein the definition of "contracted fundamental research," in a DoD contractual context, includes research performed under grants and contracts that are (a) funded by RDT&E Budget Activity 1 (Basic Research), whether performed by universities or industry or (b) funded by Budget Activity 2 (Applied Research) and performed on campus at a university.

Pursuant to DoD policy, research performed under grants and contracts that are (a) funded by Budget Activity 2 (Applied Research) and NOT performed on-campus at a university or (b) funded by Budget Activity 3 (Advanced Technology Development) or Budget Activity 4 (Advanced Component Development and Prototypes) does not meet the definition of "contracted fundamental research." In conformance with the USD (AT&L) guidance and National Security Decision Directive 189 found at https://www.acq.osd.mil/dpap/dars/pgi/docs/National_Security_Decision_Directive_189.pdf, DoD will place no restriction on the conduct or reporting of unclassified "contracted fundamental research," except as otherwise required by statute, regulation or executive order. The research shall not be considered fundamental in those rare and exceptional circumstances where the applied research effort presents a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense, and where agreement on restrictions have been recorded in the contract or grant. For certain research projects, it may be possible that although the research being performed by the prime contractor is restricted research, a subcontractor may be conducting "contracted fundamental research." In those cases, it is the prime contractor's responsibility in the proposal to identify and describe the subcontracted unclassified research and include a statement confirming that the work has been scoped, negotiated, and determined to be fundamental research according to the prime contractor and research performer.

Normally, fundamental research is awarded under grants with universities and under contracts with industry. Non-fundamental research is normally awarded under contracts and may require restrictions during the conduct of the research and DoD pre-publication review of such research results due to subject matter sensitivity. Potential Applicants should consult with the appropriate DoD Technical POCs to determine whether the proposed effort would constitute fundamental or non-fundamental research.

4. Cost Sharing or Matching

Cost sharing is not expected and will not be used as a factor during the merit review of any application hereunder. However, the Government may consider voluntary cost sharing if proposed.

5. Funding Restrictions

Section 889 of the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2019 (Public Law 115-232) prohibits the head of an executive agency from obligating or expending loan or grant funds to procure or obtain; extend, or renew a contract to procure or obtain; or enter into a contract (or extend or renew a contract) to procure or obtain the equipment, services, or systems prohibited systems as identified in section 889 of the NDAA for FY 2019.

1. In accordance with 2 CFR 200.216 and 200.471, recipients and subrecipients of all awards that are issued on or after August 13, 2020 are prohibited from obligating or expending loan or grant funds to:

    (1) Procure or obtain;
    (2) Extend or renew a contract to procure or obtain; or
    (3) Enter into a contract (or extend or renew a contract) to procure or obtain equipment, services, or systems 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 described in Public Law 115-232, section 889, covered telecommunications equipment is telecommunications equipment produced by Huawei Technologies Company or ZTE Corporation (or any subsidiary or affiliate of such entities).
        i. For the purpose of public safety, security of government facilities, physical security surveillance of critical infrastructure, and other national security purposes, video surveillance and telecommunications equipment produced by Hytera Communications Corporation, Hangzhou Hikvision Digital Technology Company, or Dahua Technology Company (or any subsidiary or affiliate of such entities).
        ii. Telecommunications or video surveillance services provided by such entities or using such equipment.
        iii. Telecommunications or video surveillance equipment or services produced or provided by an entity that the Secretary of Defense, in consultation with the Director of the National Intelligence or the Director of the Federal Bureau of Investigation, reasonably believes to be an entity owned or controlled by, or otherwise connected to, the government of a covered foreign country.

2. In implementing the prohibition under Public Law 115-232, section 889, subsection (f), paragraph (1), heads of executive agencies administering loan, grant, or subsidy programs shall prioritize available funding and technical support to assist affected businesses, institutions and organizations as is reasonably necessary for those affected entities to transition from covered communications equipment and services, to procure replacement equipment and services, and to ensure that communications service to users and customers is sustained.

3. See Public Law 115-232, section 889 for additional information.

COVERED FOREIGN COUNTRY means the People's Republic of China.

C. Program Description

The MURI program supports basic research in science and engineering at U.S. institutions of higher education (hereafter referred to as "universities") that is of potential interest to DoD. The program is focused on multidisciplinary research efforts where more than one traditional discipline interacts to provide rapid advances in scientific areas of interest to the DoD. As defined in the DoD Financial Management Regulation:

> Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. It includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. It is farsighted high payoff research that provides the basis for technological progress (DoD 7000.14-R, vol. 2B, chap. 5, para. 050105. A.)

DoD's basic research program invests broadly in many fields to ensure that it has early cognizance of new scientific knowledge.

Detailed descriptions of the topics and the Topic Chief for each can be found in Section I.1., entitled, "TOPIC DESCRIPTIONS." The detailed descriptions are intended to provide the Applicant a frame of reference and are not meant to be restrictive to the possible approaches to achieving the goals of the topic and the program. Innovative ideas addressing these research topics are highly encouraged.

Proposals from a team of university investigators are expected when the necessary expertise in addressing the multiple facets of the topics may reside in different universities. By supporting multidisciplinary teams, the program is complementary to other DoD basic research programs that support university research through single-investigator awards. Proposals shall name one Principal Investigator (PI) as the responsible technical point of contact. Similarly, one institution shall be the primary awardee for the purpose of award execution. The PI shall come from the primary institution. The relationship among participating institutions and their respective roles, as well as the apportionment of funds including sub-awards, if any, shall be described in both the proposal text and the budget.

White papers and proposals addressing the following topics should be submitted to the respective agency following the submission instructions in Section E.3.a.

Please see additional Topic Information under Section I.1. Topic Descriptions.

1. Instrument Type

The authority for awards is 10 U.S.C. 2358 in accordance with 31 U.S.C. 63. The applicable regulations are 2 CFR 200, "Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards," as implemented by 2 CFR Chapter XI, Subchapter A and DoDGARs at 32 CFR Subchapter C.

In addition, for ARO:

a. *Grant:* A legal instrument consistent with 31 U.S.C. 6304, is used to enter into a relationship:
- The principal purpose of which is to transfer a thing of value to the recipient to carry out a public purpose of support or stimulation authorized by a law or the United States, rather than to acquire property or services for the Federal Government's direct benefit or use.
- Substantial involvement is not expected between the Federal Government and the recipient when carrying out the activity contemplated by the grant.
- No fee or profit is allowed.

b. *Cooperative Agreement*: A legal instrument which, consistent with 31 U.S.C 6305, is used to enter into the same kind of relationship as a grant, except:
- Substantial involvement is expected between the Federal Government and the recipient when carrying out the activity contemplated by the cooperative agreement. No fee or profit is allowed. (For information on the substantial involvement DoD expects to have in cooperative agreements, prospective Applicants should contact the Technical Point of Contact identified in the research area of interest.)
- No fee or profit is allowed.

- In accordance with 10 U.S.C. §4021(i), as amended, the following information submitted during the solicitation and award process of Cooperative Agreement for performance of basic, applied, or advanced research authorized by section 4001 are exempt from disclosure requirements of 5 U.S.C. §552, the Freedom of Information Act (FOIA), for a period of five years from the date the Department receives the information. Offerors should mark the following documents with a legend asserting that they are submitted on a confidential basis:
  - A proposal, proposal abstract, and supporting documents;
  - A business plan submitted on a business proprietary basis;
  - Technical information submitted on a controlled basis, as outlined in DoDI 5230.24, Distribution Statements on Technical Documents.

D. Application Contents and Format

1. Content and Form of Application Submission

a. General Information

All submissions will be protected from unauthorized disclosure in accordance with applicable law and DoD regulations. Applicants are expected to appropriately mark each page of their submission that contains proprietary information. Titles given to the submissions should be descriptive of the work they cover and not be merely a copy of the title of this announcement.

Regardless of whether or not a non-MURI funded collaboration is included in the proposal (see Section B.2.), the same submission process for white papers and proposals will be followed. The proposal submission process has two stages:

- Applicants are strongly encouraged to submit a white paper; and
- Applicants must submit a proposal through Grants.gov.

Prospective awardees are encouraged to submit white papers to minimize the labor and cost associated with the production of detailed proposals that have very little chance of being selected for funding. Based on an assessment of the white papers, the responsible Research Topic Chief will provide informal feedback notification to the prospective awardees to encourage or discourage submission of proposals. The Research Topic Chief may also, on occasion, provide feedback encouraging re-teaming to strengthen a proposal.

b. White Papers

a) Format

- Paper size – 8.5 x 11-inch
- Margins – 1 inch
- Spacing – single-spaced
- Font – Times New Roman, 12-point
- Page limit – **No more than four (4) pages, single-sided pages** (excluding cover letter, cover page, references, and curriculum vitae). White paper pages beyond the 4-page limit may not be evaluated or read.

b) Content

The white papers and proposals submitted under this NOFO are expected to address unclassified basic research. White papers and proposals will be protected from unauthorized disclosure in accordance with applicable laws and DoD regulations.

Applicants are expected to appropriately mark each page of their submission that contains proprietary information.

For proposals containing data that the Applicant does not want disclosed to the public for any reason, or used by the Government except for evaluation purposes, the Applicant shall mark the title page with the following legend:

"This proposal includes data that shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed--in whole or in part--for any purpose other than to evaluate the proposal or for program coordination. If, however, a grant is awarded to this Applicant as a result of, or in connection with, the submission of this data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the resulting award. This restriction does not limit the Government's right to use information contained in this data if it is obtained from another source without restriction. The data subject to this restriction is contained in (insert numbers or other identification of sheets)."

Also, mark each sheet of data that the Applicant wishes to restrict with the following legend: "Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal."

Use of Principal Investigator (PI) Over Multiple Proposals/Topics:

Applicants contemplating the use of an individual as Principal Investigator (PI) for more than one proposal and/or topic are strongly encouraged to contact the Topic Chief(s) prior to white paper submission to determine if the Topic Chief(s) support PI participation in multiple proposals and/or topics. Support of the use of a PI over multiple proposals and/or topics is at the discretion of the Topic Chief(s).

PI participation in multiple proposals and/or topics shall be identified in all white paper submissions where the PI is proposed. The white paper should also document the amount of time the PI is available for the project(s) and how the PI will manage their time given the possibility of multiple awards.

Applicants that do not submit white papers, but wish to submit a proposal, shall document PI participation in multiple proposals and/or topics in all proposals where the PI is proposed. The proposal should also document the amount of time the PI is available for the project(s) and how the PI will manage their time given the possibility of multiple awards.

White papers shall include the following:

- The cover sheet shall include the NOFO number, proposed title, and proposer's technical point of contact, with telephone number, facsimile number, e-mail address, topic number, and topic title. (For ONR submissions please use the specific coversheet that can be downloaded at https://www.nre.navy.mil/work-with-us/how-to-apply/submit-grant-application. FedConnect will not accept a white paper unless the Cover Sheet is included.)
- The white paper shall provide:
- Identification of the research and issues
- Proposed technical approaches
- Potential impact on DoD capabilities
- Potential team and management plan
- Summary of estimated costs
- Curriculum vitae of key investigators (see Use of Principal Investigator (PI) Over Multiple Proposals/Topics)
- Identification of any Organizational Conflict(s) of Interest (if any) – See Section H.1.d.

The white paper should provide sufficient information on the research being proposed (e.g., hypothesis, theories, concepts, approaches, data measurements and analysis, etc.) to allow for an assessment by a technical expert. It is not necessary for white papers to carry official institutionalsignatures.

c. Full Proposals

Prospective Applicants must complete the mandatory forms in accordance with the instructions provided on the forms and the additional instructions below. Files that are attached to the forms must be in Adobe Portable Document Format (.PDF); cannot contain macros; and cannot be password protected. **If any attachment is not a PDF, contains macros or is password protected, they will**

not pass the automated acceptance check and will need to be resubmitted prior to the submission deadline.

Block 2, "Type of Application" on the SF-424 should be marked "New" on the resubmission.

a) Format for Technical Proposal

- Paper size – 8.5 x 11 inch
- Margins – 1 inch
- Spacing – single-spaced
- Font – Times New Roman, 12-point
- Page Limit – Technical Proposal: **25 pages***

  There are no page limitations for the budget.

***INCLUDED IN PAGE COUNT**	**NOT INCLUDED IN PAGE COUNT**
Technical Approach/Project Narrative	Everything else
Management Approach	
Principal Investigator Qualifications	

Disclosure of Conflict of Commitment and Conflict of Interest

This announcement requires that **all** current and pending research support, as defined by Section 223 of the FY21 National Defense Authorization Act must be disclosed at the time of proposal, for all covered individuals. Such disclosure will be updated annually during the performance of any research project selected for funding, and whenever covered individuals are added or identified as performing under this project. Covered individuals are those who are listed as key personnel on proposals including but not restricted to the Principal Investigator or Co-Principal Investigator.

Any decision to accept a proposal for funding under this announcement will include full reliance on the Applicant's statements. Failure to report fully and completely all sources of project support and outside positions and affiliations may be considered a materials statement within the meaning of the federal False Claims Act and constitutes a violation of law.

The funding agency may conduct a pre-award conflict of interest/conflict of commitment review of any proposal selected for funding as described in the DoD Component Decision Matrix to Inform Fundamental Research Proposal Mitigation Decisions. Offerors are advised that any significant conflict of interest/conflict of commitment identified may be a basis for the rejection of an otherwise awardable proposal.

b) Content

NOTE: The electronic file name for all documents submitted under this NOFO must not exceed 68 characters in length, including the file name extension.

Mandatory SF-424 Research and Related (R&R) Family Forms

The mandatory forms are found at https://www.grants.gov/forms/forms-repository/

i. SF-424 (R&R)

The SF-424 (R&R) form must be used as the cover page for all proposals. Complete all required fields in accordance with the "pop-up" instructions on the form and the following instructions for specific fields. Please complete the SF-424 first, as some fields on the SF-424 are used to auto-populate fields on other forms. Guidance: https://www.grants.gov/web/grants/forms/r-r-family.html.

The completion of most fields is self-explanatory with the exception of the following special instructions:

- Field 3 - Date Received by State: Leave Blank
- Field 4a - Federal Identifier:
  For ONR, enter "N00014"
  For ARO, enter "W36QYT"
  For AFOSR, enter "FA9550"
- Field 4b - Agency Routing Number:

  For ONR, enter the three (3) digit Research Topic Chief's Code and the Research Topic Chief's name (last name first) in brackets (e.g., 331 [Smith, John]). Where the Program Office Code only has two digits, add a "0" directly after the Code (e.g., Code 31 would be entered as 310).

  For ARO, enter the name of the Research Topic Chief.

  For AFOSR, enter the Research Topic Chief's Topic Number (#) and Research Topic Chief's name (last name first) in brackets (e.g., 12 [Smith, John]).

  Applicants who fail to provide a Program Officer Code identifier may receive a notice that their proposal is rejected.

- Field 4c - Previous Grants.gov Tracking ID: If this submission is for a Changed/Corrected Application, enter the Grants.gov tracking number of the previous proposal submission; otherwise, leave blank.
- Field 5 – Application Information: Email address entered by the grantee on the SF-424 application to create the Electronic Document Access (EDA) notification profile. DoD recommends that organizations provide a global business address.

- Field 7 - Type of Applicant. Complete as indicated: If the organization is a Minority-Serving Institution, select "Other" and under "Other (Specify)" note that the institution is a Minority-Serving Institution (MI).

- Field 9 - Name of Federal Agency: List the appropriate agency (i.e., ONR, AFOSR, or ARO) as the reviewing agency. This field is usually pre-populated in Grants.gov.

- Field 11 – Descriptive Title of Applicant's Project: Include "MURI:" at the beginning of your descriptive title. Include the ONR White Paper Tracking Number provided to the Applicant by ONR.

- Field 14 – Project Director/Principal Investigator: Email address entered by the grantee on the SF-424 application to create the EDA notification profile.

- Field 16 - Is Application Subject to Review by State Executive Order 12372 Process? Choose "No". Check "Program is Not Covered by Executive Order 12372."

- Field 17 – Certification: All awards require some form of certifications of compliance with national policy requirements. By checking "I Agree" on the SF-424 (R&R) block 17 you agree to abide by the following statement: "By signing this application, I certify (1) to the statements contained in the list of certifications and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. code, Title 218, Section 1001).

  For AFOSR, if you check "I agree" on SF424 block 17 and do NOT upload a completed SF-LLL Disclosure of Lobbying Activities, you are certifying that you do NOT have any lobbying activities to disclose. If you do have lobbying activities to disclose, you MUST check "I agree" on SF424 block 17 AND upload a completed SF-LLL.

- Field 19 – Authorized Representative (AOR): Email address entered by the grantee on the SF-424 application to create the EDA notification profile. Note: If the name in the signature field of Block 19 does not match the name listed as the AOR, you **must** provide signature delegation authority in the form of written approval from the named AOR or an institutional memo granting delegated signature authority.

ii. PROJECT SUMMARY/ABSTRACT

The project summary/abstract must identify the research problem and objectives, technical approaches, anticipated outcome of the research, if successful, and impact on DoD capabilities. Use only characters available on a standard QWERTY keyboard. Spell out all Greek letters, other non-English letters, and symbols. Graphics are not allowed and there is a one page or 4,000-character limit, including spaces, whichever is less.

Do not include proprietary or confidential information. The project summary/abstract must be marked by the Applicant as "Approved for Public Release". Abstracts of all funded research

projects will be posted on the public Defense Technical Information Center (DTIC) website: https://dodgrantawards.dtic.mil/grants.

iii. RESEARCH AND RELATED OTHER PROJECT INFORMATION

- Fields 1 and 1a – Human Subject Use: Each proposal must address human subject involvement in the research by completing Fields 1 and 1a of the R&R Other Project Information form. For proposals containing activities that include or may include "research involving human subject" as defined in DoDI 3216.02, prior to award, **the Applicant must submit the required documentation under "Use of Human Subjects in Research" (Section H.1.).**

- Fields 2 and 2a – Vertebrate Animal Use: Each proposal must address animal use protocols by addressing Fields 2 and 2a of the R&R Other Project Information form. If animals are to be utilized in the research effort proposed, **the Applicant must submit the documents described under "Use of Animals" (Section H.1.).**

- Fields 4a through 4d – Environmental Compliance: Address these fields and briefly indicate whether the intended research will result in environmental impacts outside the laboratory, and how the Applicant will ensure compliance with environmental statutes and regulations.

  Federal agencies making grant or cooperative agreement awards and recipients of such awards must comply with all applicable environmental planning and regulatory compliance requirements. The National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. § 4321 et seq., for example, requires that agencies consider the environmental impact of "major Federal actions" prior to any final agency decision. With respect to those awards which constitute "major Federal actions," as defined in 40 CFR 1508.18, federal agencies may be required to comply with NEPA and prepare environmental planning documentation such as an environmental impact statement (EIS), even if the agency does no more than provide grant funds to the recipient. Most field research funded by DoD, however, constitute activities covered by a NEPA categorical exclusion that do not require preparation of further environmental planning documentation. This is particularly true with regard to basic and applied scientific research conducted entirely within the confines of a laboratory, if the research complies with all other applicable safety, environmental, and natural resource conservation laws. Questions regarding NEPA or other environmental planning or regulatory compliance issues should be referred to the technical point of contact.

- Field 7 – Project Summary/Abstract: Leave Field 7 blank; complete Form SF-424 Project Abstract. If an error message occurs when leaving Block 7 blank, upload the Project Abstract.

- Field 8 – Project Narrative: Clearly describe the research, including the objective and approach to be performed, keeping in mind the evaluation criteria. Attach the entire proposal narrative to R&R Other Project Information form in Field 8. To attach a Project Narrative to Field 8, click on "Add attachment" and attach the technical proposal as a single PDF file. Save the file as "Technical Proposal" as typing in the box is prohibited.

  The technical proposal must describe the research in sections as described below:

- **Cover Page (<u>not</u> included in page count):** This must include the words "Technical Proposal" and the following:
  - ONR: NOFO Number: N0001425SF002; or
  - ARO: W911NF25S0004; or
  - AFOSR: NOFOAFRLAFOSR2025002
  - Title of proposal;
  - Identity of prime Applicant and complete list of subawardees, if applicable;
  - Technical contact (name, address, phone/fax, email address);
  - Administrative/business contact (name, address, phone/fax, email address); and
  - Proposed period of performance (identify both the base period and options, if included).

- **Table of Contents (<u>not</u> included in page count):** An alphabetical/numerical listing of the sections within the proposal, including corresponding page numbers.

- **Technical Approach (included in page count):** Describe in detail the objectives and scientific or technical concepts that will be investigated, explaining the complete research plan, and how the data will be analyzed. Describe what is innovative about the proposed approach. Discuss the relationship of the proposed research to the state-of-the-art knowledge in the field and to related efforts in programs elsewhere and discuss potential scientific breakthroughs. Include appropriate literature citations/references. Given the successful completion, describe the results, new knowledge, or insights. The Technical Approach section should include:

  - **Future DoD Relevance:** A description of potential DoD relevance and contributions of the effort to the agency's specific mission.
  - **Project Schedule and Milestones:** A summary of the schedule of events and milestones.

- **Management Approach (included in page count):** Describe how and how often the Principal Investigator will communicate with the Co-Investigators, how data will be made available within the team, and how differences of opinion might be resolved. Describe the research and management responsibilities of the team members. Describe plans for the research training of students. Include the number of time equivalent graduate students and undergraduates, if any, to be supported each year. Discuss the involvement of other students, if any.

- **Principal Investigator Qualifications (included in page count):** A discussion of the qualifications of the proposed Principal Investigator and any other key personnel.

- **Data Management Plan (<u>not</u> included in page count):** A data management plan is a document that describes which data generated through the course of the proposed research will be shared and preserved and how this will be done, explains why data sharing or preservation is not possible or scientifically appropriate, or why the costs of sharing or preservation are incommensurate with the value of doing so. See also: DoD Instruction 3200.12.

- In no more than 2 pages, discuss the following:
    - The types of data, software, and other materials to be produced.
    - How the data will be acquired.
    - Time and location of data acquisition, if scientifically pertinent.
    - How the data will be processed.
    - The file formats and the naming conventions that will be used.
    - A description of the quality assurance and quality control measures during collection, analysis, and processing.
    - A description of dataset origin when existing data resources are used.
    - A description of the standards to be used for data and metadata format and content.
    - Appropriate timeframe for preservation.
    - The plan may consider the balance between the relative value of data preservation and other factors such as the associated cost and administrative burden. The plan will provide a justification for such decisions.
    - A statement that the data cannot be made available to the public when there are national security or controlled unclassified information concerns (e.g., "This data cannot be cleared for public release in accordance with the requirements in DoD Directive 5230.09.")

- Field 9 – Bibliography & References Cited: Upload your Bibliography/References Cited as a single PDF.

- Field 10 – Facilities & Other Resources: Describe facilities available for performing the proposed research and any additional facilities the Applicant proposes to acquire at their own expense. Indicate government-owned facilities already possessed that will be used. (Additional equipment will not be provided unless the research cannot be completed by any other practical means.)

- Field 11 – Equipment: Describe any equipment available or any additional equipment the applicant proposes to acquire at their own expense. Indicate government owned equipment that will be used. Justify the need for each equipment item. (Additional equipment will not be provided unless the research cannot be completed by any other practical means.)

- Field 12 – Other Attachments: Optional, as necessary.

Grants do not include the delivery of software, prototypes, or other hardware deliverables.

iv. RESEARCH AND RELATED BUDGET

The Applicant must use the Grants.gov forms (including the Standard Form (SF) Research and Related (R&R) Budget Form) from the application package template associated with the NOFO on the Grants.gov website located at http://www.grants.gov/. If options are proposed, the cost proposal must provide the pricing information for the option periods; failure to include the proposed costs for the option periods will result in the options not being included in the award. The Applicant shall provide a detailed cost breakdown of all costs, by cost category.

There should be a detailed breakdown of all costs, by cost category, and by the calendar periods stated below. For budget purposes, use an award start date of 01 May 2024. Note that the budget for each of the calendar periods below should include only those costs to be expended during that calendar period. The budget should also include an option for two additional years.

For proposals to **ONR topics**, the Recommended Funding Profile is:

(1) FY26: Six months (01 May 26 to 31 Oct 26): $750,000
(2) FY27: Twelve months (01 Nov 26 to 31 Oct 27): $1,500,000
(3) FY28: Twelve months (01 Nov 27 to 31 Oct 28): $1,500,000
(4) FY29: Six months (01 Nov 28 to 30 Apr 29): $750,000
Three-year base subtotal: $4,500,000

(4) FY29: Six months (01 May 29 to 30 Oct 29): $750,000
(5) FY30: Twelve months (01 Nov 29 to 30 Oct 30): $1,500,000
(6) FY31: Six months (01 Nov 30 to 30 Apr 31): $750,000
Two-year option subtotal: $3,000,000
Five-year total: $7,500,000

For proposals to **ARO topics**, the Recommended Funding Profile is:

(1) FY26: Five months (01 May 26 to 30 Sep 26): $625,000
(2) FY27: Twelve months (01 Oct 26 to 30 Sep 27): $1,500,000
(3) FY28: Twelve months (01 Oct 27 to 30 Sep 28): $1,500,000
(4) FY29: Seven months (01 Oct 28 to 30 Apr 29: $875,000
Three-year base subtotal: $4,500,000

(4) FY29: Five months (01 May 29 to 30 Sep 29): $625,000 (Option)
(5) FY30: Twelve months (01 Oct 29 to 30 Sep 30): $1,500,000
(6) FY31: Seven months (01 Oct 30 to 30 Apr 31): $875,000
Two-year option subtotal: $3,000,000
Five-year total: $7,500,000

For proposals to **AFOSR topics**, the Recommended Funding Profile is:
(1) FY26: Twelve months (01 May 26 to 30 Apr 27): $1,500,000
(2) FY27: Twelve months (01 May 27 to 30 Apr 28): $1,500,000
(3) FY28: Twelve months (01 May 28 to 30 Apr 29): $1,500,000
Three-year base subtotal: $4,500,000

(4) FY29: Twelve months (01 May 29 to 30 Apr 30): $1,500,000
(5) FY30: Twelve months (01 May 30 to 30 Apr 31): $1,500,000
Two-year option subtotal: $3,000,000
Five-year total: $7,500,000

The available budget is subject to change based on the availability of funds.

NOTE: AFOSR will not consider any request for exception above $15,000,000 including additional funding and cost-sharing.

A separate **Adobe.pdf** document **must** be included in the application that provides appropriate justification and/or supporting documentation for each element of cost proposed. This document shall be attached under Section K. "Budget Justification" of the Research and Related Budget form. Click "Add Attachment" to attach. All costs should be rounded to the nearest dollar. The itemized budget should include the following.

- Direct Labor – Individual labor categories or persons, with associated labor hours and unburdened direct labor rates. Provide escalation rates for outyears.

- Administrative and Clerical Labor – Salaries of administrative and clerical staff are normally indirect costs (and included in an indirect cost rate). Direct charging of these costs may be appropriate when a major project requires an extensive amount of administrative or clerical support significantly greater than normal and routine levels of support. Budgets proposing direct charging of administrative or clerical salaries must be supported with a budget justification which adequately describes the major project and the administrative and/or clerical work to be performed.

- Fringe Benefits - Fringe benefits are allowable provided that the benefits are reasonable and are required by law, non-Federal entity-employee agreement, or an established policy of your institution (2 CFR 200.431). Please attach a copy of your institution's fringe benefits rate agreement.

- Indirect Costs (Facilities and Administration (F&A), Overhead, G&A, etc.) – The proposal should show the rates and calculation of the costs for each rate category. If the rates have been approved/negotiated by a Government agency, you must provide a copy of the memorandum/agreement. If the non-Federal entity has never received a negotiated indirect cost rate, they may elect to charge a de minimis rate of 10% of modified total direct costs or provide sufficient detail to enable a determination of allowability, allocability and reasonableness of the allocation bases, and how the rates are calculated. See 2 CFR 200.414(f) regarding the use of a de minimis rate.

- Travel – The proposed travel cost **must** include the following details for each trip: the purpose of the trip, origin and destination if known, approximate duration, the number of travelers, and the estimated cost per trip must be justified based on the organizations historical average cost per trip or other reasonable basis for estimation. Such estimates and the resultant costs claimed must conform to the applicable Federal cost principles. Applicants may include travel costs for the Principal Investigator to attend the peer reviews described in Section H of this NOFO. A sample Travel Estimate Spreadsheet with the required information is located at the following link: https://www.nre.navy.mil/work-with-us/how-to-apply/submit-grant-application

- Subawards/Subcontracts – Provide a description of the work to be performed by the subrecipient/subcontractor. For each subaward, a detailed cost proposal is required to be

submitted by the subrecipient(s) using the R&R budget form. The same requirements for the individual categories identified in this section apply to the subaward/subcontract. **Include subrecipient(s) name at the top of the budget justification document.** A proposal and any supporting documentation must be received and reviewed before the Government can complete its cost analysis of the proposal and enter negotiations. DoD's preferred method of receiving subcontract information is for this information to be included with the prime proposal. However, a subcontractor's cost proposal can be provided in a sealed envelope with the recipient's cost proposal or via e-mail directly to the Program Officer at the same time the prime proposal is submitted. The e-mail should identify the proposal title and the prime Applicant and state that the attached proposal is a subcontract.

- Consultants – Provide a breakdown of the consultant's hours, the hourly rate proposed, and any other proposed consultant costs, a copy of the signed Consulting Agreement or other documentation supporting the proposed consultant rate/cost, and a copy of the consultant's proposed statement of work if it is not already separately identified in the prime Applicant's proposal.

- Materials & Supplies – Provide an itemized list of all proposed materials and supplies including quantities, unit prices, and the basis for the estimate (e.g., quotes, prior purchases, catalog price lists).

- Recipient Acquired Equipment or Facilities – Equipment and/or facilities are normally furnished by the Recipient. If acquisition of equipment and/or facilities is proposed, a justification for the purchase of the items must be provided. Provide an itemized list of all equipment and/or facilities costs and the basis for the estimate (e.g., quotes, prior purchases, catalog price lists). Allowable items normally are limited to research equipment not already available for the project. General purpose equipment (i.e., equipment not used exclusively for research, scientific, or other technical activities, such as personal computers, laptops, office equipment) should not be requested unless they will be used primarily or exclusively for the project. For computer/laptop purchases and other general-purpose equipment, if proposed, include a statement indicating how each item of equipment will be integrated into the program or used as an integral part of the research effort. Applicants **must** provide vendor quotes for any proposed capital equipment costs.

- Other Direct Costs – Provide an itemized list of all proposed other direct costs such as Graduate Assistant tuition, laboratory fees, and report and publication costs, and the basis for the estimate (e.g., quotes, prior purchases, catalog price lists).

- Fee/Profit – Fee/profit is unallowable under assistance agreements at either the prime or subaward level but may be permitted on contracts issued by the prime awardee.

v. RESEARCH AND RELATED SENIOR/KEY PERSON PROFILE (EXPANDED)

To evaluate compliance with Title IX of the Education Amendments of 1972 (20 U.S.C. A§ 1681 Et. Seq.), the Department of Defense is collecting certain demographic and career information to be able to assess the success rates of women who are proposed for key roles in applications in STEM disciplines. In addition, the National Defense Authorization Act (NDAA) for FY 2019, Section

1286, directs the Secretary of Defense to protect intellectual property, controlled information, key personnel, and information about critical technologies relevant to national security and limit undue influence, including foreign talent programs by countries that desire to exploit United States' technology within the DoD research, science and technology, and innovation enterprise.

The R&R Senior/Key Person Profile (Expanded) form has inputs to collect both "biosketch" and "current and pending support" by using the common forms located at https://www.nsf.gov/bfa/dias/policy/nstc_disclosure.jsp.

The R&R Senior/Key Person Profile (Expanded) form will be used to collect the following information for all senior/key personnel, including Project Director/Principal Investigator and Co-Project Director/Co-Principal Investigator, whether or not the individuals' efforts under the project are to be funded by the DoD:

- Degree Type and Degree Year fields as the source for career information.
- Upload the biosketch/CV/resume (limited to 5 pages per CV) to the Biographical Sketch field.
- Current & Pending Support (no page limit): Applicants shall include a list of **all** current projects the individual is working on, in addition to any future support the individual has applied to receive, regardless of the source. Upload this document by clicking "Add Attachment." The following information shall be included for each current or pending project:
    - Title and objectives
    - The percentage per year to be devoted to the other projects
    - The total amount of support the individual is receiving in connection to each of the other research projects or will receive if the other proposals are awarded
    - Name and address of the agencies and/or other parties supporting the other research projects
    - Period of performance for the other research projects

Additional senior/key persons can be added by selecting the "Next Person" button. Note that, although applications without these fields completed may pass Grants.gov edit checks, if DoD receives an application without the required information, DoD may determine that the application is incomplete and may return it without further review. DoD reserves the right to request further details from the Applicant before making a final determination on funding the effort.

vi. RESEARCH AND RELATED PERSONAL DATA

This form will be used by DoD as the source of demographic information, such as gender, race, ethnicity, and disability information for the Project Director/Principal Investigator and all other persons identified as Co-Project Director(s)/Co-Principal Investigator(s). Each application must include this form with the name fields of the Project Director/Principal Investigator and any Co-Project Director(s)/Co-Principal Investigator(s) completed; however, provision of the demographic information in the form is voluntary. If completing the form for multiple individuals, each Co-

Director/Co-Principal Investigator can be added by selecting the "Next Person" button. The demographic information may be accessible to the reviewer but will not be considered in the evaluation. Applicants who do not wish to provide some or all the information should check or select the "Do not wish to provide" option.

E. Submission Requirements and Deadlines

1. Address to Request Application Package

This NOFO may be accessed from the sites below. Amendments, if any, to this NOFO will be posted to these websites when they occur. Interested parties are encouraged to periodically check these websites for updates and amendments.

- Grants.gov: www.grants.gov
- ONR website: https://www.nre.navy.mil/work-with-us/funding-opportunities
- AFOSR website: https://www.afrl.af.mil/About-Us/Fact-Sheets/Fact-Sheet-Display/Article/2282103/afosr-funding-opportunities/
- ARO website: https://arl.devcom.army.mil/collaborate-with-us/opportunity/muri/

2. Unique Entity Identifier (UEI) and System for Award Management (SAM)

All Applicants submitting proposals or applications **must**:

a) Be registered in SAM prior to submission;
b) Provide a valid UEI number in each application or proposal it submits to the agency; and
c) Maintain an active SAM registration with current information at all times during which it has an active Federal award or an application under consideration by a Federal awarding agency.

SAM may be accessed at https://www.sam.gov/SAM.

A Federal awarding agency may not make a Federal award to an Applicant/offeror until the Applicant has complied with all applicable unique entity identifier and SAM requirements and, if an Applicant/offeror has not fully complied with the requirements by the time the Federal awarding agency is ready to make a Federal award, the Federal awarding agency may determine that the Applicant/offeror is not qualified to receive a Federal award and use that determination as a basis for making a Federal award to another Applicant/offeror.

3. Submission Instructions

a. White Paper Submission Instructions

ONR utilizes FedConnect for the submission of white papers. FedConnect is a web portal that bridges the gap between government agencies and performers to streamline the process of doing business with the government. Through this portal, performers will be able to review opportunities and submit white papers. To access FedConnect go to https://www.fedconnect.net/FedConnect/default.htm.

Important Note: In addition to the FedConnect submission, offerors shall also submit a confirmation email to the ONR TPOC that they have submitted a white paper to FedConnect.

a) How to register for FedConnect

FedConnect how to guide can be found at https://www.fedconnect.net/FedConnect/Marketing/Documents/FedConnect_Ready_Set_Go.pdf.
See pages 25 through 33 of the FedConnect Ready Set Go guide for step-by-step instructions on how to submit your documents.

i. Register with SAM

All organizations applying online through FedConnect must register with the System for Award Management (SAM) and will receive a unique entity identifier (UEI) number. Failure to register with SAM will prevent your organization from applying through FedConnect. SAM registration must be renewed annually. If you have not registered in SAM, go to https://www.sam.gov/SAM/.

If you are the first person in your organization to register in FedConnect, your SAM Marketing Partner ID (SAM MPIN) will also be required. It is the number that is set up by your organization as part of the registration in SAM.gov.

ii. Create a FedConnect account:

The next step in the registration process is to create an account with FedConnect.

b) FedConnect Assistance

If you need assistance, the FedConnect Support Team is standing by to assist you.

Email: fcsupport@unisonglobal.com
Phone: 1-800-899-6665
Hours: Monday – Friday, 8 a.m. to 8 p.m. EDT. Closed on Federal holidays.

FedConnect Frequently Asked Questions can be found on the ONR website at https://www.nre.navy.mil/work-with-us/how-to-apply/frequently-asked-questions.

NOTE: DO NOT USE THE FEDCONNECT MESSAGE CENTER TO SUBMIT QUESTIONS OR WHITE PAPERS. PLEASE FOLLOW THE WHITE PAPER SUBMISSION

INSTRUCTIONS IN THE FEDCONNECT HOW-TO GUIDE, OR SUBMIT QUESTIONS VIA EMAIL TO THE APPROPRIATE AGENCY CONTACT LISTED IN SECTION G.

b. Full Proposal Submission Instructions

a) Grants.gov Application Submission and Receipt Procedures

This section provides the application submission and receipt instructions for the Department of Defense (DoD) agency program applications. Please read the following instructions carefully and completely.

i. Electronic Delivery

DoD is participating in the Grants.gov initiative to provide the grant community with a single site to find and apply for federal grant funding opportunities. All Applicants shall submit their applications online through Grants.gov.

ii. How to Register for Grants.gov

(1) *Instructions:* Read the instructions below about registering to apply for DoD funds. Applicants should read the registration instructions carefully and prepare the information requested before beginning the registration process. Reviewing and assembling the required information before beginning the registration process will alleviate last-minute searches for required information.

Organizations must have an active System for Award Management (SAM) registration, and Grants.gov account to apply for grants. If individual Applicants are eligible to apply for this funding opportunity, then you may begin with step 3, Create a Grants.gov account, listed below.

Creating a Grants.gov account can be completed online in minutes, but SAM registrations may take up to 7-10 days. Therefore, an organization's registration should be done in sufficient time to ensure it does not impact the entity's ability to meet requirement application submission deadlines.

Complete organization instructions can be found on Grants.gov here:
https://www.grants.gov/applicants/applicant-registration

1) *Register with SAM*: All organizations applying online through Grants.gov must register with the System for Award Management (SAM). Failure to register with SAM will prevent your organization from applying through Grants.gov. SAM registration must be renewed annually. For more detailed instructions for registering with SAM, refer to:
https://www.grants.gov/applicants/applicant-registration

2) *Create a Grants.gov Account*: The next step in the registration process is to create an account with Grants.gov. Follow the on-screen instructions provided on the registration page.

3) *Add a Profile to a Grants.gov Account:* A profile in Grants.gov corresponds to a single Applicant organization the user represents (i.e., an Applicant) or an individual Applicant. If you work for or consult with multiple organizations and have a profile for each, you may log in to one

Grants.gov account to access all of your grant applications. To add an organizational profile to your Grants.gov account, enter the UEI Number for the organization in the UEI field while adding a profile. For more detailed instructions about creating a profile on Grants.gov, refer to https://www.grants.gov/applicants/applicant-registration/ebiz-poc-authorizes-profile-roles

4) *EBiz POC Authorize Profile Roles:* After you register with Grants.gov and create an Organization Applicant Profile, the organization Applicant's request for Grants.gov roles and access is sent to the EBiz POC. The EBiz POC will then log in to Grants.gov and authorize the appropriate roles, which may include the Authorized Organization Representative (AOR) role, thereby giving you permission to complete and submit applications on behalf of the organization. You will be able to submit your application online any time after you have been assigned the AOR role. For more detailed instructions about authorizing roles on Grants.gov, refer to https://www.grants.gov/applicants/applicant-registration/ebiz-poc-authorizes-profile-roles

5) *Track Role Status*: To track your role request, refer to: https://www.grants.gov/applicants/applicant-registration/track-profile-role-status

(2) *Electronic Signature*: When applications are submitted through Grants.gov, the name of the organization's AOR that submitted the application is inserted into the signature line of the application, serving as the electronic signature. The EBiz POC **must** authorize individuals who are able to make legally binding commitments on behalf of the organization as an AOR; **this step is often missed and it is crucial for valid and timely submissions.**

b) How to Submit an Application to ONR, ARO, or AFOSR via Grants.gov

White Papers must **NOT** be submitted through the Grants.gov application process. White paper submissions to ONR must be submitted through FedConnect.

All attachments to grant applications submitted through Grants.gov must be in Adobe Portable Document Format. Proposals with attachments submitted in word processing, spreadsheet, or any format other than Adobe Portable Document Format will not be considered for award.

Grants.gov Applicants can apply online using Workspace. Workspace is a shared, online environment where members of a grant team may simultaneously access and edit different web forms within an application. For each notice of funding opportunity (NOFO), you can create individual instances of a workspace.

Below is an overview of applying on Grants.gov. For access to complete instructions on how to apply for opportunities, refer to: https://www.grants.gov/applicants/workspace-overview

1) *Create a Workspace*: Creating a Workspace allows you to complete it online and route it through your organization for review before submitting.

2) *Complete a Workspace*: Add participants to the Workspace, complete all the required forms, and check for errors before submission. The Workspace progress bar will display the state of your

application process as you apply. As you apply using Workspace, you may click the blue question mark icon near the upper-right corner of each page to access context-sensitive help.

a. *Adobe Reader*: If you decide not to apply by filling out web forms you can download individual PDF forms in Workspace so that they will appear similar to other Standard Forms. The individual PDF forms can be downloaded and saved to your local device storage, network drive(s), or external drives, then accessed through Adobe Reader.

   NOTE: Visit the Adobe Software Compatibility page on Grants.gov to download the appropriate version of the software at: https://www.grants.gov/applicants/adobe-software-compatibility

b. *Mandatory Fields in Forms:* In the forms, you will note fields marked with an asterisk and a different background color. These fields are mandatory fields that must be completed to successfully submit your application.

c. *Complete SF-424 Fields First*: The forms are designed to fill in common required fields across other forms, such as the Applicant name, address, and UEI number. To trigger this feature, an Applicant must complete the SF-424 information first. Once it is completed, the information will transfer to the other forms.

3) *Submit a Workspace*: An application may be submitted through Workspace by clicking the Sign and Submit button on the Manage Workspace page, under the Forms tab. **Grants.gov recommends submitting your application package at least 24-48 hours prior to the close date** to provide you with time to correct any potential technical issues that may disrupt the application submission.

4) *Track a Workspace*: After successfully submitting a Workspace package, a Grants.gov Tracking Number (GRANTXXXXXXXX) is automatically assigned to the package. The number will be listed on the Confirmation page that is generated after submission. Using the tracking number, access the Track My Application page under the Applicants tab or the Details tab in the submitted workspace.

For additional training resources, including video tutorials, refer to:
https://www.grants.gov/applicants/applicant-training

c. Applicant Support

Grants.gov provides Applicants 24/7 support via the toll-free number 1-800-518-4726 and email at support@grants.gov. For questions related to the specific grant opportunity, contact the number listed in the application package of the grant for which you are applying.

If you are experiencing difficulties with your submission, it is best to call the Grants.gov Support Center and get a number. The Support Center ticket number will assist DoD with tracking your issue and understanding background information on the issue.

4. Submission Dates and Times

See Section A.7 above, "Key Dates" for information.

F. Application Review Information

1. Timely Receipt Requirements and Proof of Timely Submission

a. Online Submission

All applications must be received by **5:00 PM Eastern Time on 22 AUGUST 2025**. Proof of timely submission is automatically recorded by Grants.gov. An electronic date/time stamp is generated within the system when the application is successfully received by Grants.gov. The Applicant AOR will receive an acknowledgement of receipt and a tracking number (GRANTXXXXXXXX) from Grants.gov with the successful transmission of their application. Applicant AORs will also receive the official date/time stamp and Grants.gov Tracking number in an email serving as proof of their timely submission.

When the DoD agency successfully retrieves the application from Grants.gov, and acknowledges the download of submissions, Grants.gov will provide an electronic acknowledgment of receipt of the application to the email address of the Applicant with the AOR role. Again, proof of timely submission shall be the official date and time that Grants.gov receives your application. Applications received by Grants.gov after the established due date for the program will be considered late and will not be considered for funding by the DoD agency.

Applicants using unreliable internet connections should be aware that the process of completing the Workspace can take some time. Therefore, applicants should allow enough time to prepare and submit the application before the package closing date. Grants.gov will provide either an error or a successfully received transmission in the form of an email sent to the applicant with the AOR role attempting to submit the application. The Grants.gov Support Center reports that some applicants end the transmission because they think that nothing is occurring during the transmission process. Please be patient and give the system time to process the application.

DoD strongly recommends submitting applications no later than two (2) business days ahead of submission deadline to ensure sufficient time for any corrections that may be required.

b. Proposal Receipt Notice

After a proposal is submitted through Grants.gov, the Authorized Organization Representative (AOR) will receive a series of three emails. It is extremely important that the AOR watch for and save each of the emails. You will know that your proposal has reached the DoD agency when the AOR receives email Number 3. You will need the Submission Receipt Number (email Number 1) to track a submission. The three emails are:

- Number 1 – The Applicant will receive a confirmation page upon completing the submission to Grants.gov. This confirmation page is a record of the time and date stamp that is used to determine whether the proposal was submitted.
- Number 2 – The Applicant will receive an email indicating that the proposal has been validated by Grants.gov within two days of submission (This means that all of the required fields have been completed). After an institution submits an application, Grants.gov generates a submission receipt via email and also sets the application status to “Received.” This receipt verifies the application has been successfully delivered to the Grants.gov system. Next, Grants.gov verifies the submission is valid by ensuring it does not contain viruses, the opportunity is still open, and the Applicant login and Applicant UEI number match. If the submission is valid, Grants.gov generates a submission validation receipt via email and sets the application status to “Validated.” If the application is not validated, the application status is set to "Rejected." The system sends a rejection email notification to the institution, and the institution must resubmit the application package. Applicants can track the status of their application by logging in to Grants.gov.
- Number 3 – The third notice is an acknowledgment of receipt via email from DoD within ten days from the proposal due date, if applicable. The email is sent to the authorized representative for the institution. The email notes that the proposal has been received and provides the assigned tracking number.

2. Review Criteria

Basic Research: The MURI Program is funded by a basic research appropriation. White papers and proposals, in order to be considered for funding, are therefore required to be of a basic, rather than applied or advanced technological, nature.

Note that basic research includes “scientific study and experimentation directed toward increasing fundamental knowledge and understanding” while applied research deals with the development of “useful materials, devices, and systems or methods” and “the design, development, and improvement of prototypes and new processes to meet general mission area requirements.” The full definitions of these terms are contained in document: (DoD 7000.14-R, vol. 2B, chap. 5, para. 050105)

White papers will be evaluated to assess whether the proposed research is likely to meet the objectives of the specific topic, and thus whether to encourage the submission of a proposal. The assessment of the white papers will primarily focus on scientific and technical merits, potential for the research to significantly advance fundamental understanding in the topic area, and potential DoD interest.

Proposals responding to this NOFO in each topic area will be evaluated using the following criteria:

- Scientific and technical merits of the proposed basic science and/or engineering research;
- Potential for the research, if successful, to significantly advance fundamental understanding in the topic area;

- Potential DoD relevance and contribution to the DoD mission;
- Qualifications and availability of the Principal Investigator and other investigators;
- Adequacy of current or planned facilities and equipment to accomplish the research objectives;
- Impact of interactions with other organizations engaged in related research and development, in particular DoD laboratories, industry, and other organizations that perform research and development for defense applications; and
- Realism and reasonableness of cost (cost sharing is not a factor in the evaluation)

3. Review and Selection Process

a. Evaluation

The ultimate recommendation for award of proposals is made by the DoD's scientific/technical community. Recommended proposals will then be forwarded to ONR, AFOSR, or ARO Contracts and Grant Awards Management office. Any notification received from the DoD agency that indicates that the Applicant's proposal has been recommended does not guarantee an award will ultimately be made. This notice indicates that the proposal has been selected in accordance with the evaluation criteria stated above and has been sent to the Grants Department to conduct cost analysis, determine the Applicant's responsibility, to confirm whether funds are available, and to take other relevant steps necessary prior to commencing negotiations with the Applicant.

b. Options

The Government will evaluate options for award purposes by adding the total cost for all options to the total cost for the basic requirement. Evaluation of options will not obligate the Government to exercise the options during contract or grant performance. The Government reserves the right to exercise options at time of award.

c. Evaluation Panel

White paper submissions will be reviewed either solely by the responsible Research Topic Chief for the specific topic or by an evaluation panel chaired by the responsible Research Topic Chief. An evaluation panel will consist of technical experts who are Government employees or who are detailed under the Intergovernmental Personnel Act (IPA). Restrictive notices notwithstanding, one or more support contractors or advisors external to the US Government may be utilized as subject-matter-expert technical consultants. These individuals will sign a conflict of interest statement and a non-disclosure agreement prior to receiving proposal information.

Proposals will undergo a multi-stage evaluation procedure. The Research Topic Chief and other Government scientific experts will perform the evaluation of technical proposals first. Cost proposals will be evaluated by Government business professionals. Restrictive notices notwithstanding, one or more support contractors or advisors external to the US Government may be utilized as subject-matter-expert technical consultants. However, proposal selection and award decisions are solely the responsibility of Government personnel. Support contractor employees and advisors external to the US Government having access to technical and cost proposals submitted in response to this NOFO will be required to sign a non-disclosure and a conflict of interest statement prior to receipt of any proposal submission. Findings of the evaluation panels will be forwarded to senior DoD officials who will make funding recommendations to the awarding officials.

Due to the nature of the MURI program, the evaluation panels and reviewing officials may on occasion recommend that less than an entire MURI proposal be selected for funding. This may be due to several causes, such as insufficient funds, research overlap among proposals received, or potential synergies among proposals under a research topic. In such cases, proposal adjustments will be agreed to by the Principal Investigator and the Government prior to final award.

4. Risk Review

The Grants Officer is responsible for determining a recipient's qualification prior to award. In general, a Grants Officer will award grant and cooperative agreements only to qualified recipients that meet the standards at 32 CFR 22.415. To be qualified, a potential recipient must:

- Have the management capability and adequate financial and technical resources, given those that would be made available through the grant or cooperative agreement, to execute the program of activities envisioned under the grant or cooperative agreement;
- Have a satisfactory record of executing such programs or activities (if a prior recipient of an award);
- Have a satisfactory record of integrity and business ethics; and
- Be otherwise qualified and eligible to receive a grant or cooperative agreement under applicable laws and regulations. Applicants are requested to provide information with proposal submissions to assist the Grants Officer's evaluation of recipient qualification.

a. Risk-based Security Review Process

All Covered Individuals proposed under all grants and cooperative agreements are subject to the DoD Fundamental Research Risk-Based Security Review Process. In accordance with applicable laws and regulations and as designated by DoD policy, Covered Individuals are individuals who contribute in a substantive, meaningful way to the scientific development or execution of a research and development project, including the principal investigator (PI) and co-PI(s).

This risk-based security review process provides consistency in policy and procedures across all DoD Components. Risk-based security reviews will be conducted for all fundamental research proposals that are identified as "selected for award based on technical merit." The risk-based security reviews will be conducted by reviewing the Standard Form (SF) 424, "Senior/Key Person Profile (Expanded)," its accompanying or referenced documents, Common Disclosure Forms, and the Research Performance Progress Reports (when applicable), in concert with a risk decision matrix consistent with DoD's Decision Matrix to Inform Fundamental Research Proposal Mitigation Decisions.

University or non-profit research institution performance under this solicitation will be efforts categorized as fundamental research. In addition to Government support for free and open scientific exchanges and dissemination of research results in a broad and unrestricted manner, the academic or non-profit research performer or recipient, regardless of tier, acknowledges that such research may have implications that are important to U.S. national interests and must be protected against foreign influence and exploitation. As such, the academic or non-profit research performer or recipient agrees to comply with the following requirements:

i. On June 8, 2023, the Undersecretary of Defense for Research and Engineering (OUSD (R&E)) released a memorandum, "Policy on Risk-Based Security Reviews on Fundamental Research," directing Components to establish a risk-based security review program to identify and mitigate undue foreign influence in fundamental research consistent with the requirements mandated by National Security Presidential Memorandum (NSPM)-33. In accordance with these requirements, all Covered Individuals proposed under all fundamental research proposals that are selected for award will be assessed for potential undue foreign influence risk factors relating to professional and financial activities. This will be done by evaluating information provided via the SF-424 and any accompanying or referenced documents, as well as the Common Disclosure Forms and Research Performance Progress Reports, as applicable, to identify and assess any associations or affiliations the Covered Individuals may have with foreign countries of concern (FCOC) (i.e., The Peoples Republic of China, the Russian Federation, the Islamic Republic of Iran, and the Democratic People's Republic of North Korea) or FCOC connected entities.

ii. The University or non-profit research institution, performer, or recipient agrees to provide information on potential conflicts of interest and conflicts of commitment associated with foreign influence in their biographical sketch and current and pending support.

    (a) The above-described information will be provided to the Government as part of the proposal response to the solicitation and will be reviewed and assessed utilizing a risk-based security review process prior to award. Generally, this information will be included in the Research and Related Senior/Key Personnel Profile (Expanded) form (SF-424) and Common Disclosure Forms required as part of the proposer's submission through Grants.gov.

        1. Instructions regarding how to fill out the SF-424 and its biographical sketch and current and pending support can be

found through Grants.gov.

(b) The risk-based security review process takes into consideration the entirety of the Covered Individual's SF-424, Common Disclosure Forms, current and pending support, and biographical sketch. Any identified potential risk factors, along with publicly or commercially available validation information, are then compared to a risk decision matrix consistent with the "DoD Component Decision Risk Matrix to Inform Fundamental Research Proposal Mitigation Decisions" to determine the level of mitigation that may be required to proceed, if possible.

(c) The risk-based security review process will leverage, among other things, publicly available lists or reports published by the U.S. federal government and cited in the "Decision Matrix to Inform Fundamental Research Proposal Mitigation Decisions": https://basicresearch.defense.gov/Portals/61/Documents/Academic%20Research%20Security%20Page/DoD%20Component%20Decision%20Matrix%20to%20Inform%20Fundamental%20Research%20Proposal%20Mitigation%20Decisions.pdf?ver=GQHK7CJBr8ks5GPnXKxabQ%3d%3d .

(d) Congress has explicitly stated that there are foreign influence risks that are not able to be mitigated and thus would require denial of award. They are:

1. Beginning 1 October 2023, no U.S. institution of higher education that hosts a Confucius Institute* may receive DoD funding. Institutions hosting a Confucius Institute are automatically classified as "prohibited" under OUSD(R&E)'s "Policy on Risk Based Security Reviews on Fundamental Research," as required by law.
2. Beginning 9 August 2024, the DoD is prohibited from funding or making an award of a fundamental research project proposal in which a Covered Individual is actively participating in a malign foreign talent recruitment program, pursuant to section 10632 of the CHIPS and Science Act of 2022. Individuals participating in such a program are automatically classified as "prohibited" under OUSD(R&E)'s "Policy on Risk Based Security Reviews on Fundamental Research," as required by law.

* The term "Confucius Institute" means a cultural institute directly or indirectly funded by the Government of the People's Republic of China.

(e) Any changes to Covered Individuals will require submission of an SF-424 and its attachments, Common Disclosure Forms, a security-based risk assessment, and approval by the contracting officer and program manager.

(f) Security-based risk assessments will also be conducted if changes to Covered Individuals reporting criteria are reflected in the Research Performance Progress Reports.

(g) To the greatest extent practicable, the DoD will work with the proposing institution to ensure that if the risk is able to be mitigated, it will make every

effort to do so. If the proposing institution refuses to, or is unable to mitigate the identified risks, it may result in a denial of award.

(h) Proposing institutions who have their technically acceptable fundamental research proposal rejected due to the risk-based security review process may challenge the risk-based security review decision. In that instance, the OUSD(R&E) will reconsider the project proposal as well as any additional documentation provided by the proposing institution to ensure that the risk-based security review was performed consistent with OUSD(R&E) policy.

(i) This process, to include negotiation of risk mitigation measures, is not to be considered as part of the time-to-award.

iii. Involvement of Covered Individuals in Malign Foreign Talent Recruitment Programs.

(a) If, at any time during performance of this research award, the academic or non- profit research performer or recipient should learn that it, its Covered Individuals, or applicable team members or subtier performers on this award are, or are believed to be, participants in a malign foreign government talent program or exhibiting behaviors/actions identified in the DoD Component Decision Matrix to Inform Fundamental Research Proposal Mitigation Decisions (i.e., funding from a FCOC or FCOC-connected entity, patents resulting from U.S. government funded research that were filed with a FCOC or on behalf of a FCOC-connected entity, and associations or affiliations with foreign government connected entities), the performer or recipient will notify the Government Contracting Officer or Agreements Officer within 5 business days.

1. This disclosure must include specific information as to the personnel involved and the nature of the situation and relationship. The Government will have 30 business days to review this information and conduct any necessary fact-finding or discussion with the performer or recipient.

2. Such disclosure could result in a termination of award at the government's discretion.

3. If the University receives no response from the Government to its disclosure within 30 business days, it may presume that the Government has determined the disclosure does not represent a threat.

(b) The performer or recipient must flow down this provision to any subtier contracts or agreements involving direct participation in the performance of the research.

iv. All analysis and assessment of affiliations and associations of Covered Individuals are compliant with Title VI of the Civil Rights Act of 1964. Information regarding race, color, or national origin is not collected and does not have bearing in the risk assessment. University or non-profit research institutions with proposals selected for negotiation that have been assessed as having potential undue foreign influence risk

factors, as defined by the DoD Decision Matrix to Inform Fundamental Research Proposal Mitigation Decisions, will be given an opportunity during the negotiation process to mitigate the risk. The DoD reserves the right to request any follow-up information needed to assess potential risk factors or proposed risk mitigation strategies.

v. Definitions: Definitions can be found in the June 08, 2023 USD(R&E) memorandum, "Policy for Risk Based Security Reviews of Fundamental Research," or as it is amended.

AFOSR-SPECIFIC RISK REVIEW INFORMATION

Each proposal submission will be subject to a Risk-based Security Review prior to selection for award. The Risk-based Security Review is applied to federally funded research designed to help protect Department of the Air Force Science and Technology (S&T) by identifying possible vectors of undue foreign influence. AFRL will follow all policy and procedures outlined in Air Force Research Laboratory (AFRL) Instruction AFRLI 61-113, Science and Technology Protection for the Air Force Research Laboratory and Department of the Air Force Instruction DAFI 63-101/20-101, Integrated Lifecycle Management. The Risk-based Security Review will be conducted in accordance with OUSD(R&E)'s "Policy for Risk Based Security Reviews of Fundamental Research"

i. **Security risk review for these subject proposals will be developed for all proposed Senior/Key personnel and "Covered Individuals."** These risk reviews will be based on information disclosed in a Research and Related Senior and Key Person Profile. In addition, any accompanying or referenced documents, and publicly available information will be utilized in risk reviews. Nationality or citizenship is not a factor in the security risk reviews.

External Engagements. When considering all external engagements, AFRL incorporates a holistic decision-making process that encompasses technical and security factors. The security review method implemented by AFRL measures risk factors to identify the appropriate Risk Acceptance Level (RAL) within the organization. The objective analysis of the security risk factors is conducted to empower AFRL's S&T leaders to make risk-informed decisions. The review process looks at the risk factors indicated in the DoD Component Decision Matrix to Inform Fundamental Research Proposal Mitigation Decisions.

ii. **Actions Required by Applicants/Recipients at Proposal Submission**
In accordance with AFRLI 61-113, S&T Protection, Applicants/Recipients are required to submit the following documentation with their proposal:

- Standard Form 424, "Research and Related Senior and Key Person Profile (Expanded) (Included in Application Package), AND;
- Common Disclosure Forms for biosketch and current and pending support (to be submitted with SF-424), AND;

- "Privacy Act Statement" consent form for each Covered Individual that is also signed by the Applicants/Recipients as the Individual's Sponsors (See "Covered Individual" section below and Attachment 1)

In the event a security risk is identified, and the Government has determined the security risk exceeds the acceptable threshold and cannot be mitigated, the Applicant/Recipient will be notified and informed of the decline of award. The Government will provide an unclassified rationale for any rejection of a proposal due to security risks.

By submission of the Research and Related Senior Key Person Profile, the Applicant/Recipient agrees to comply with the following:

- To certify that each covered individual who is listed on the application has been made aware: 1) of all relevant disclosure requirements, including the requirements of 42 U.S.C. § 6605; and 2) that false representations may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802. See National Science and Technology Council Guidance for Implementing National Security Presidential Memorandum 33 (NSPM-33) on National Security Strategy for United States Government-Supported Research and Development (January 2022).

iii. **Actions Required by Covered Individuals**

- Covered Individual. An individual who contributes to a substantive, meaningful way to the scientific development or execution of a research and development project proposed to be carried out with a research and development award from a federal research agency; and is designated as a covered individual by the federal research agency concerned. See 42 U.S.C. § 6605, Definitions. (Note: For purposes of a Notice of Funding Opportunity (NOFO) solicitation, "covered individuals" are all Senior/Key Personnel.)
- Federal law requires that all current and pending research support, as defined by 42 U.S.C. §6605, must be disclosed at the time of proposal submission, for all covered individuals. The Government may require an updated disclosure during the performance of any research project selected for funding. The Government will require an updated disclosure whenever covered individuals are added or identified as performing under the funded project.
- Covered Individuals are also required to sign the "Privacy Act Statement" and provide such signed statement to the Applicant/Recipient for submission with the proposal. (See Attachment 1).
- Any decision to accept a proposal for funding under this announcement will include full reliance on the individual's statements. Failure to report fully and completely all sources of project support and outside positions and affiliations may be considered a material statement within the meaning of the False Claims Act, 31 U.S.C. 3729, and constitute a violation of Federal law.

iv. **Actions Required by Applicants/Recipients During Period of Performance**

- Applicant/Recipient will utilize a section of the Research Progress Performance Report (RPPR) to provide disclosure updates for Senior/Key Research Personnel. In addition, whenever a new covered individual(s) is to be added or identified as performing under the funded project, a new Research and Related Senior and Key Person Profile will be required prior to continued performance.
- If, at any time, during performance of this award, the Applicant/Recipient learns that its Senior/Key Research Personnel (including any sub awardee personnel who receive this designation) are or are believed to be participants in a Foreign Government Talent Program or have Foreign Components with a strategic competitor or country with a history of targeting U.S. technology for unauthorized transfer, the Applicant/Recipient will notify the Contracting/Grants/Agreements Officer within five (5) business days of awareness.
- This disclosure must include specific information as to the personnel involved and the nature of the situation and relationship. The Government will review this information and conduct any necessary fact-finding or discussion with the Applicant/Recipient. The Government's determination on disclosure may include acceptance, mitigation, or termination of the award.
- The Applicant/Recipient will be required to flow down this provision to all sub awardees who have personnel designated as Senior/Key Research Personnel as a result of their involvement in the performance of the research.

v. **No Guaranteed Award**

- AFOSR does not guarantee that any award will be made under this competition

vi. **Disclosure of Administrative Processing by Contractor Personnel**

- AFOSR use support contractor personnel to help it with administrative proposal processing. The contractor personnel are employees of commercial firms that have a contract with AFOSR. AFOSR makes sure all of its support contracts include nondisclosure agreements that prohibit disclosure of any information you submit to other parties.

b. FAPIIS

In accordance with Office of Management and Budget (OMB) guidance in parts 180 and 200 of Title 2, CFR, it is DoD policy that DoD Components must report and use integrity and performance information in the Federal Awardee Performance and Integrity Information System (FAPIIS), or any successor system designated by OMB, concerning grants and cooperative agreements as follows:

If the total Federal share will be greater than the simplified acquisition threshold on a Federal award under a Notice of Funding Opportunity (see 2 CFR 200.88 Simplified Acquisition Threshold):

i. The Federal awarding agency, prior to making a Federal award with a total amount of Federal share greater than the simplified acquisition threshold, will review and consider any information about the Applicant that is in the designated integrity and performance system accessible through SAM (currently FAPIIS) (see 41 U.S.C. 2313);

ii. An Applicant, at its option, may review information in the designated integrity and performance systems accessible through SAM and comment on any information about itself that a Federal awarding agency previously entered and is currently in the designated integrity and performance system accessible through SAM;

iii. The Federal awarding agency will consider any comments by the Applicant, in addition to the other information in the designated integrity and performance system, in making a judgment about the Applicant's integrity, business ethics, and record of performance under Federal awards when completing the review of risk posed by Applicants as described in 2 CFR 200.205 Federal awarding agency review of risk posed by Applicants.

G. Federal Award Notices

1. Email

All Applicants will receive a notification email advising if their proposal has been selected or not selected for award.

Applicants whose proposals are recommended for award may be contacted by a Grant Specialist to discuss additional information required for award. This may include representations and certifications, revised budgets or budget explanations, and/or other information as applicable to the proposed award.

The notification e-mail must not be regarded as an authorization to commit or expend funds. The Government is not obligated to provide any funding until a Government Grants Officer, as applicable, signs the award document.

The award document signed by the Contracting Officer or Grants Officer is the official and authorizing award instrument.

- For ARO: ARO emails their awards/modification documents to the awardees.

- For AFOSR: AFOSR emails their awards/modification documents to the awardees.
- For ONR: ONR award/modification documents are only available via the Department of Defense (DoD) Electronic Document Access System (EDA) within the Procurement Integrated Enterprise Environment (https://piee.eb.mil/). EDA is a Web-based system that provides secure online access, storage and retrieval of awards and modifications to DoD employees and vendors.

H. Post-Award Requirements and Administration

1. Administrative and National Policy Requirements

Any assistance instrument awarded under this announcement will be governed by the award terms and conditions that conform to DoD's implementation of Office of Management and Budget (OMB) guidance applicable to financial assistance, as well as each respective agency's terms and conditions.

For ONR, ARO, and AFOSR: The DoD Terms and Conditions are located at https://www.nre.navy.mil/work-with-us/manage-your-award/manage-grant-award/grants-terms-conditions

(i) Export Control

Applicants should be aware of recent changes in export control laws. Applicants are responsible for ensuring compliance with all U.S. export control laws and regulations, including the International Traffic in Arms Regulation (ITAR)(22 CFR Parts 120 - 130) and Export Administration Regulation (EAR) (15 CFR Parts 730 – 774), as applicable. In some cases, developmental items funded by the Department of Defense are now included on the United States Munition List (USML) (22 CFR Part 121) and are therefore subject to ITAR jurisdiction. In other cases, items that were previously included on the USML have been moved to the EAR Commerce Control List (CCL). Applicants should address in their proposals whether ITAR or EAR restrictions apply to the work they are proposing to perform for DoD. The ITAR and EAR are available online at http://www.ecfr.gov/cgi-bin/ECFR?page=browse. Additional information regarding the President's Export Control Reform Initiative can be found at https://www.export.gov/article2?id=Export-Control-Reform-ECR.

Applicants must comply with all U.S. export control laws and regulations, including the ITAR and EAR, in the performance of any award or agreement resulting from this NOFO. Applicants shall be responsible for obtaining any required licenses or other approvals, or license exemptions or exceptions if applicable, for exports of hardware, technical data, and software (including deemed exports), or for the provision of technical assistance.

(ii) Requirements Concerning Live Organisms:

a) Use of Animals:

The DoD policies and requirements for the use of animals in DoD-supported research are described in the DoD Instruction 3216.01, "Use of Animals in DoD Conducted and Supported Research and Training," and its implementing instruction, DHA-MSR 6025.02, "The Care and Use of Animals in DoD Research, Development, Test, and Evaluation (RDT&E) or Training Programs." If animals are to be utilized in the research effort proposed, the Applicant must submit a Full Appendix or Abbreviated Appendix (see Guidance link below) with supporting documentation (such as copies of Institutional Animal Care and Use Committee (IACUC) Approval, IACUC Approved Protocol, and most recent United States Department of Agriculture (USDA) Inspection Report) prior to award. For assistance with submission of animal research related documentation, contact the appropriate DoD Agency's Animal Use Administrator.

- ONR: Ms. Suzanne May, 703-696-4318, Suzanne.B.May.civ@us.navy.mil. Guidance: https://www.nre.navy.mil/work-with-us/how-to-apply/compliance-and-protections/research-protections/animal-use
- AFOSR: Dr. Brett J. Taylor, Colonel, U.S. Army Veterinary Corps, 703-681-860, brett.j.taylor2.mil@mail.mil
- ARO: Ms. Theresa M. Straut, 410-278-5928, theresa.m.straut.civ@army.mil

b) Use of Human Subjects in Research:

1. Applicants must protect the rights and welfare of individuals who participate as human subjects in research awarded pursuant to this NOFO and must comply with the requirements of the Common Rule at 32 CFR part 219 (the DOD implementation of 45 CFR part 46) and applicable provisions of DoD Instruction 3216.02, Protection of Human Subjects and Adherence to Ethical Standards in DoD-Conducted and -Supported Research (April 15, 2020, the DON implementation of the human research protection program contained in SECNAVINST 3900.39E Change 1, (or its replacement), 10 USC 980 "Limitation on Use of Humans as Experimental Subjects," and when applicable, Food and Drug Administration (FDA) and other federal and state law and regulations.

2. For proposals containing activities that include or may include "research involving human subjects" as defined in DoDI 3216.02, prior to award, the Applicant must submit documentation of:
   a. Approval from an Institutional Review Board (IRB) (IRB-approved research protocol, IRB-approved informed consent document, documentation showing the IRB considered the scientific merit of the research and other material considered by the IRB); proof of completed human research training (e.g., training certificate for the Principal Investigator, and institutional verification that the Principal Investigator, Co-Investigators, and research support personnel have received appropriate training to be considered qualified to execute the research); and the Applicant's Department of Health and Human Services (DHHS)-

issued Federal Wide Assurance (FWA#), including notifications of any FWA suspensions or terminations.

b. Any claimed exemption under 32 CFR 219.104, including the category of exemption, supporting documentation considered by the Applicant's institution in making the determination (e.g., protocol, data collection tools, advertisements, etc.). The documentation shall include a short rationale supporting the exemption determination. This documentation should be signed by the IRB Chair or IRB vice Chair, designated IRB administrator or official of the Applicant's human research protection program.

c. Any determinations that the proposal does not contain activities that constitute research involving human subjects or contains only activities that are deemed not to be research under 32 CFR 219.102(1), including supporting documentation considered by the Applicant's institution in making the determination. This documentation should be issued by the IRB Chair or IRB vice Chair, designated IRB administrator or official of the Applicant's human research protection program.

d. Documentation must be submitted to the appropriate DoD Agency Human Research Protection Office (HRPO), by way of the DoD Agency Program Officer. The HRPO retains final judgment on whether the documentation satisfies the use of human subjects in research requirements. For assistance with submission of human subject research related documentation, contact:

- ONR: Ms. Suzanne May, Human Research Protection Official (HRPO), 703-696-4318, mailto:Suzanne.B.May.civ@us.navy.mil
- AFOSR: Ms. Sherrie L. Pryber, 937-656-5468, AFRL.IR.HRPO@us.af.mil
- ARO: Ms. Theresa M. Straut, 410-278-5928, theresa.m.straut.civ@army.mil

e. Grant awards and any subawards or modifications will include a statement indicating successful completion of the HRPO review. Research involving human subjects must not be commenced under any contract award or modification or any subcontract or grant subaward or modification until awardee receives notification from the Contracting or Grants Officer that the HRPO has approved the assurance as appropriate for the research under the award or modification and thatthe HRPO has reviewed the protocol and accepted the IRB approval or determination for compliance with Federal and DoD research protection requirements. The Government will not reimburse or otherwise pay for work performed in violation of this requirement. See, DFARS 252.235-7004.

(iii) Biosafety and Biosecurity Requirements:

Applicants must comply with applicable provisions of the current version of DODM 6055.18, Safety Standards for Microbiological and Biomedical Laboratories, including ensuring compliance with standards meeting at least the minimum applicable requirements of the current edition of Centers for Disease Control and Prevention, "Biosafety in Microbiological and Biomedical Laboratories (BMBL)," and National Institutes of Health, "The NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines)."

(iv) Research Involving Recombinant (rDNA) or Synthetic Nucleic Acid Molecules:

Applicants must not begin performance of research within the scope of "The NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines)" until receiving notice from the Contracting or Grants Officer that ONR has reviewed and accepted the Applicant's documentation. In order for ONR to accomplish that review, an Applicant must provide the Contracting or Grants Officer, generally as part of an original proposal prior to award, sufficient documentation to enable the review, including:

(1) A written statement that the Applicant is in compliance with NIH Guidelines. This statement should be made by an official of the institution other than the Principal Investigator and should be on university or company letterhead.
(2) Evidence demonstrating that the proposed research protocol has been approved (or determined exempt from the NIH Guidelines) by an Institutional Biosafety Committee (IBC); and a copy of the Department of Health and Human Services (DHHS) Letter of Approval of the IBC, or the most recent letter from DHHS stating the IBC is in compliance with the NIH Guidelines. For assistance with requirements involving countries outside the United States, please contact the ONR HRPO at (703) 696-4318.

(v) Institutional Dual Use Research of Concern:

As of September 24, 2015, all institutions and United States Government (USG) funding agencies subject to the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern must comply with all the requirements listed therein. If your research proposal directly involves certain biological agents or toxins, contact the cognizant Technical Point of Contact. U.S. Government Science, Safety, Security (S3) guidance may be found at http://www.phe.gov/s3/dualuse.

(vi) Department of Defense High Performance Computing Program:

The DoD High Performance Computing Program (HPCMP) furnishes the DoD S&T and RDT&E communities with use-access to very powerful high performance computing systems. Awardees of ONR grants and other assistance instruments may be eligible to use HPCMP assets in support of their funded activities if ONR Program Officer Approval is obtained and if security/screening requirements are favorably completed. Additional information and an application may be found at https://www.hpc.mil/.

(vii) Project Review Meetings and Program Review Meetings:

Individual Project Review Meetings between the DoD sponsor and the performer may be held as necessary. Project Review Meetings typically last approximately one day. Typically, there are two in-person Project Review Meetings each year. Additional Project Review Meetings are likely, but these will be accomplished by video telephone conferences, telephone conferences, or web-based collaboration tools.

In addition to Project Review Meetings, Program Review Meetings may be held to provide a forum for reviews of the latest results from individual project experiments and any other incremental project progress towards major demonstrations. Program Review Meetings are generally held once per year and last two to three days.

For cost estimating purposes, Applicants should budget for two in-person meetings. In FY24 and beyond, review meetings may be held local to the funding DoD Agency or other government or non-government facilities within the continental United States.

The Government sometimes finds it advantageous to hold Program Review Meetings at a performer's facility. Applicants interested in hosting such meetings should include an estimated cost and the following language in their proposals, which become part of any award (note: if a contract is awarded, use of the facility will be included as an option):

> [Name of entity] offers the use of its facilities for a DoD Program Review Meeting to discuss the status of programs related to the subject of this proposal. Such meetings may include attendees representing multiple research efforts. The meetings will discuss only "contracted fundamental research" as provided in the Under Secretary of Defense (Acquisition, Technology and Logistics) Memorandum of 24 May 2010, the results of which are open to the public. No fee will be charged Program Review Meeting attendees. [Name of entity] understands it will not be asked to host a Performance Review Meeting more than once per year, if at all.

Applicants are not required to include the foregoing term in their proposals, and whether they do or not will not affect their selection for award.

(viii) Federal Funding Accountability and Transparency Act of 2006:

The Federal Funding Accountability and Transparency Act of 2006 (Public Law 109-282), as amended by Section 6202 of Public Law 110-252 and expanded by the Digital Accountability and Transparency Act of 2014 (Public Law 113-101), requires that all agencies establish requirements for recipients reporting information on subawards and executive total compensation as codified in 2 CFR Part 170. Any company, non-profit agency or university that applies for financial assistance (either grants, cooperative agreements or TIAs) as either a prime or sub-recipient under this NOFO must provide information in its proposal that describes the necessary processes and systems in place to comply with the reporting requirements identified in 2 CFR Part 170 Appendix A. Entities are required to meet reporting requirements unless an exception or exemption applies. Please refer to 2 CFR Part 170, including Appendix A, for a detailed explanation of the requirements, exceptions, and exemptions.

(ix) Financial Assistance Certification:

The Federal Assistance Certifications Report is an attestation that the entity will abide by the requirements of the various laws and regulations and the supplemental at Section F.2.iv above. Therefore, as applicable, you are still required to submit any documentation, including the Standard

Form-LLL “Disclosure Form to Report Lobbying” (if applicable), and disclosure of any unpaid delinquent tax liability or a felony conviction under any Federal law.

Note for AFOSR: By checking "I Agree" on the SF 424 (R&R) block 17 you agree to fully comply with the Lobbying Disclosure Act of 1995, 2 U.S.C. § 1601 et seq. If your grant amount exceeds $100,000 you are certifying that you do not have lobbying activity to disclose. If you have lobbying activity that you must disclose under 31 U.S.C. 1352 as implemented by the DoD in 32 CFR Part 2 you must attach the completed SF-LLL Disclosure of Lobbying Activities. You can find instructions for completing this form at http://www.whitehouse.gov/sites/default/files/omb/grants/sflllin.pdf.

Unpaid Delinquent Tax Liability or a Felony Conviction under Any Federal Law – DoD Appropriations

By checking "I Agree" on the SF 424 (R&R) block 17 you represent that you are not a corporation that has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in timely manner pursuant to an agreement with the authority responsible for collecting the tax liability; AND that you represent that you are not a corporation that was convicted of a felony criminal violation under any Federal law within the preceding 24 months.

Note: If you do not represent to this you are ineligible to receive an award unless a Federal agency suspension and debarment official (SDO) has considered suspension or debarment and determined that further action is not required to protect the Government’s interests. The applicant therefore should provide information about its tax liability or conviction to the agency’s SDO as soon as it can do so, to facilitate completion of the required consideration before award decisions are made.

(x) Certifications Regarding Restrictions on Lobbying:

Grant awards greater than $100,000 require a certification of compliance with a national policy mandate concerning lobbying. Grant Applicants shall provide this certification by electronic submission of SF-424 (R&R) as a part of the electronic proposal submitted via https://www.grants.gov/ (complete Block 17). The following certification applies likewise to each grant seeking federal assistance funds exceeding $100,000:

(1) No Federal appropriated funds have been paid or will be paid by or on behalf of the Applicant, to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the Federal contract, grant, loan, or cooperative agreement, the

Applicant shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.
(3) The Applicant shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by 31 U.S.C. 1352. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

(xi) Certifications Regarding the Prohibition on Using Funds with Entities that Require Certain Internal Confidentiality Agreements (Grant Information Circular (GIC) 19-02 November 2019) (Supplement to SF-424 (R&R), block 17, Financial Assistance Certifications and Representations)

By checking "I Agree" on the SF-424 (R&R) block 17 you agree to abide by the following statement: "By signing this application, I certify (1) to the statements contained in the list certifications and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. code, Title 218, Section 1001)."

The certification reads as follows:

> By submission of its proposal or application, the Applicant represents that it does not require any of its employees, contractors, or subrecipients seeking to report fraud, waste, or abuse to sign or comply with internal confidentiality agreements or statements prohibiting or otherwise restricting those employees, contractors, or subrecipients from lawfully reporting that waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information.

(xii) Certification Regarding Disclosure of Funding Sources (Supplement to SF-424, block 17, Financial Assistance Certifications and Representations

By checking "I Agree" on the SF-424 (R&R) block 17 you agree to abide by the following statement: "By signing this application, I certify the proposing entity is in compliance with Section 223(a) of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 which requires that: (a) the PI and other key personnel certify that the current and pending support provided on the proposal is current, accurate and complete; (b) agree to update such disclosure at the request of the agency prior to the award of support and at any subsequent time the agency determines appropriate during the term of the award; and (c) the PI and other key personnel have been made

aware of the requirements under Section 223(a)(1) of this Act. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. code, Title 218, Section 1001)."

(xiii) Conflict of Interest

Applicants for assistance are required to comply with 2 CFR 200.318(c), Codes of Conduct, to prevent real or apparent conflicts of interest in the award and administration of any contracts by which a recipient or subrecipient purchases property or services, supported by federal funds.

a) General Requirement for Disclosure

You and your organization must disclose any potential or actual scientific or nonscientific conflict(s) of interest to us. You must also disclose any potential or actual conflict(s) of interest for any identified sub recipient you include in your application. We may ask you more questions if we need more information.

At our discretion, we may ask you for a conflict of interest mitigation plan after you submit your application. Your plan is subject to our approval.

b) Scientific Conflict of Interest

Scientific collaborations on research and development projects are generally the result of close collaboration prior to the submission of applications for support. Accordingly, these collaborations should be considered when considering potential conflicts of interest. The potential conflict is mitigated by the disclosure of these collaborations, and the list of current and pending support you provide for senior and key researchers. Therefore, you must include in your list of current and pending support all collaborators, even if they did not formally provide support.

(xiv) Code of Conduct

Applicants for assistance are required to comply with 2 CFR 200.318(c), Codes of Conduct, to prevent real or apparent conflicts of interest in the award and administration of any contracts supported by federal funds. This provision will be incorporated into all assistance instruments awarded under this NOFO.

(xv) Peer Review

In the case of proposals funded as basic research, DoD may utilize peer reviewers from academia, industry, and Government agencies to assist in the periodic appraisal of performance under the

awards. Such periodic peer reviews monitor the quality of funded basic research efforts. The reviews are used in part to determine which basic research projects will receive continued DoD funding. Peer reviewers who are not U.S. Government employees must sign nondisclosure agreements before receiving full or partial copies of proposals and reports submitted by the basic research performers. Applicants may include travel costs for the Principal Investigator (PI) to attend the peer review. Peer reviews may consider information derived from individual project or program review meetings (see NOFO Section F.2.a.viii for further guidance).

(xvi) Requirements for Operation and Procurement of Commercial Off the Shelf Unmanned Aircraft Systems

(1) Commercial Off-The-Shelf Unmanned Aircraft Systems (COTS UAS) may not be purchased pursuant to this grant or assistance agreement or contract or other transaction agreement for prototype until a Cyber Exception to Policy (ETP) is obtained by the cognizant ONR Program Officer.

(2) Exception. A Cyber ETP is not required when the research is supported via a grant award AND it is unclassified and funded with either basic research funds (i.e., 6.1) or applied research funds (i.e., 6.2) and performed on campus by a university. For all other grants and assistance agreements, a Cyber ETP must be obtained prior to purchase and/or flight operations.

(3) Notwithstanding (2) above, a Cyber ETP is required for all efforts (regardless of award or funding type) that involve interactions with military personnel, DoD property, or DoD facilities; work conducted by US Government laboratories, UARCs, or FFRDCs; or are Public Aircraft Operation (PAO), classified, or explore specific military utility. For these efforts, and depending on the UAS platform and Cyber Operating Environment, a Cyber ETP, FAA issued Certificate of Airworthiness or a NAVAIR Airworks Authority to Operate (ATO) must be obtained.

(4) Prospective or current performers are required to notify the cognizant ONR Program Officer of any anticipated COTS UAS purchase that may be subject to exception at time of white paper, proposal submission or award changes. Performers shall provide documentation specifying the details including the type of drone, effort, location, etc.

(5) Performers will agree to cooperate and provide additional information as requested to support the cyber vulnerability assessment and other requirements identified above in (3).

Notwithstanding, procedures and requirements identified above, restrictions identified in Section 848 of the National Defense Authorization Act for Fiscal Year 2023, Pub. L. No. 116-92, 10 U.S.C 4871 note, as amended, continue to apply. Performers are notified that effective October 1, 2024 additional restrictions will apply to new awards, extensions, or renewals of existing contracts. See 10 U.S.C. 4871 Note for additional information on restrictions.

In no event shall federal funding be expended or purchase made pursuant to any award subject to waiver requirement, unless and until performer is notified by DoD that the waiver, cyber vulnerability assessment, and other requirements have been met.

2. Reporting

a. If the Federal share of any Federal award includes more than $500,000 over the period of performance, the post award reporting requirements, Award Term and Condition for Recipient Integrity and Performance Matters (2 CFR Part 200 Appendix XII), are applicable as follows:

   i. Reporting of Matters Related to Recipient Integrity and Performance

      a) General Reporting Requirement. If the total value of your currently active grants, cooperative agreements, and procurement contracts from all Federal awarding agencies exceeds $10,000,000 for any period of time during the period of performance of this Federal award, then you as the recipient during that period of time must maintain the currency of information reported to the System for Award Management (SAM) that is made available in the designated integrity and performance system (currently the Federal Awardee Performance and Integrity Information System (FAPIIS)) about civil, criminal, or administrative proceedings described in paragraph 2 of this award term and condition. This is a statutory requirement under 41 U.S.C. 2313. All information posted in the designated integrity and performance system on or after April 15, 2011, except past performance reviews required for Federal procurement contracts, will be publicly available.

   ii. Proceedings about Which You Must Report. Submit the information required about each proceeding that:

      a) Is in connection with the award or performance of a grant, cooperative agreement, or procurement contract from the Federal Government;
      b) Reached its final disposition during the most recent five-year period; and
      c) Is one of the following:
         1) A criminal proceeding that resulted in a conviction, as defined in paragraph 5 of this award term and condition;
         2) A civil proceeding that resulted in a finding of fault and liability and payment of a monetary fine, penalty, reimbursement, restitution, or damages of $5,000 or more;
         3) An administrative proceeding, as defined in paragraph 5. of this award term and condition, that resulted in a finding of fault and liability and your payment of either a monetary fine or penalty of $5,000 or more or reimbursement, restitution, or damages in excess of $100,000; or
         4) Any other criminal, civil, or administrative proceeding if:
            a. It could have led to an outcome described in paragraph 2.c. (1), (2), or (3) of this award term and condition;
            b. It had a different disposition arrived at by consent or compromise with an acknowledgment of fault on your part; and

c. The requirement in this award term and condition to disclose information about the proceeding does not conflict with applicable laws and regulations.

iii. Reporting Procedures. Enter in the SAM Entity Management area the information that SAM requires about each proceeding described in paragraph 2 of this award term and condition. You do not need to submit the information a second time under assistance awards that you received if you already provided the information through SAM because you were required to do so under Federal procurement contracts that you were awarded.

iv. Reporting Frequency. During any period of time when you are subject to the requirement in paragraph 1 of this award term and condition, you must report proceedings information through SAM for the most recent five-year period, either to report new information about any proceeding(s) that you have not reported previously or affirm that there is no new information to report. Recipients that have Federal contract, grant, and cooperative agreement awards with a cumulative total value greater than $10,000,000 must disclose semiannually any information about the criminal, civil, and administrative proceedings.

v. Definitions. For purposes of this award term and condition:

a) Administrative proceeding means a non-judicial process that is adjudicatory in nature in order to make a determination of fault or liability (e.g., Securities and Exchange Commission Administrative proceedings, Civilian Board of Contract Appeals proceedings, and Armed Services Board of Contract Appeals proceedings). This includes proceedings at the Federal and State level but only in connection with performance of a Federal contract or grant. It does not include audits, site visits, corrective plans, or inspection of deliverables.
b) Conviction, for purposes of this award term and condition, means a judgment or conviction of a criminal offense by any court of competent jurisdiction, whether entered upon a verdict or a plea, and includes a conviction entered upon a plea of nolo contendere.
c) Total value of currently active grants, cooperative agreements, and procurement contracts includes—
   1) Only the Federal share of the funding under any Federal award with a recipient cost share or match; and
   2) The value of all expected funding increments under a Federal award and options, even if not yet exercised.

b. Post Award Reporting Requirements

For ONR: The post award reporting requirements can be found under the relevant ONR Addendum to the DoD R&D General Terms and Conditions and ONR Programmatic Requirements located at the following link: https://www.nre.navy.mil/work-with-us/manage-your-award/manage-grant-award/grants-terms-conditions.

For ARO: For detailed submission and formatting instructions, see ARO Reporting Instructions (Form 18),"Reporting Instructions," found at: https://arl.devcom.army.mil/wp-content/uploads/sites/3/2022/09/Form18_Sep_2022.pdf

For AFOSR: Federal-wide Research Progress Performance Report (RPPR) for interim, annual, and final research performance reports. Interim and Final Reports will be submitted to https://community.apan.org/wg/afosr/p/deliverables. Additionally, reminder emails on all interim and final RPPRs may be sent out as a courtesy.

SPECIAL NOTE: Pending Federal-wide Research Progress Performance Report (RPPR) Format.

A Federal-wide Research Progress Performance Report (RPPR) for interim, annual, and final research performance reports is under development. Performers do not have to use the RPPR now but DoD plans to use the RPPR in the future.

We may issue an award modification that requires you to use the Government-wide RPPR after a final notice is issued in the Federal Register.

I. Other Information

1. TOPIC DESCRIPTIONS

Topic 1: (AFOSR) Characterization and Modeling of the Mesosphere and Lower Thermosphere

Background*:* The mesosphere and lower thermosphere, at about 50- 120 km altitude, is often called the "ignorosphere" due to being too high for investigations using balloons and too low for probing with satellites. The addition of significant and increasing quantities of human-made materials to the region, primarily via ablation of spacecraft during reentry and emissions from spacecraft fuel systems due to the increase in launches and mega-constellations to LEO, is requiring scientists to quantify how increased human activity is modifying the upper atmosphere. Reliable and accurate models of the upper atmosphere will be increasingly essential to manage potential VLEO assets, to predict or adapt to abrupt changes to atmospheric plasma concentrations and must account for these new materials present in the atmosphere. Yet, currently, no effective model of thermospheric winds exists, and the reactivity of new materials now being added in the upper atmosphere is unknown. Reactions of such metals are complicated by the multiplicity of electron spin states they possess whose effects on reactivity are not well understood or described by existing theoretical and computational chemical methods. These spin-effects can create large barriers to some metal-atom reaction pathways creating the need for experimental and theoretical studies to determine what forces control this reactivity, hence determining the dominant reservoir species and the chemical mechanisms and networks that control them. There is a gap in information about the chemical composition, size distribution, movement, and abundance of novel elements introduced to the thermosphere in this altitude range which cannot be addressed in a scalable way with existing techniques. While several methods have been developed to monitor upper atmospheric winds, temperatures, and component densities from the ground, including meteor radars, rockets, and various lidar methodologies, new remote sensing methods and tools are needed to make this probing more accessible to many US scientists, and provide the large streams of data needed for improved assimilative modeling at a larger range of altitudes. Current atmospheric models do not include the possible chemistry and radiative transfer effects of black carbon particles or introduced metals, particularly aluminum, to the mesosphere or stratosphere. Predicted impacts from the first estimates of these species to the upper atmosphere are both not well understood and expected to be large. Developing a fundamental understanding of the forces that control the sources of materials in this region, and their behavior, is essential to properly model the behavior in this region based on solid foundational information. A wide-ranging, collaborative, multidisciplinary effort is needed to expand and improve ground- or satellite-based monitoring of chemical concentrations and dynamics in the upper atmosphere, to determine relevant chemistries via laboratory studies, to incorporate such data into existing or improved atmospheric models, to use those models to better specify current and future atmospheric conditions (e.g. density, temperature, chemical composition), and to understand the impacts of those conditions on Earth systems and LEO and VLEO space resiliency.

Objective: The objective of this program is to develop the fundamental and comprehensive understanding needed to accurately characterize, model, and predict the behavior of species in the upper atmosphere, particularly the impact on atmospheric chemistry and dynamics. A multidisciplinary effort is needed that includes remote sensing, atmospheric modeling, chemical kinetics, mechanisms, and dynamics, to collect and assimilate the needed understanding and data, and collaboratively develop predictive models.

Research Concentration Areas: Suggested research areas include but are not limited to 1) Development of novel tools and methods that would enable accessible and scalable ground-based sensing methods for accurately determining the concentrations of major and less prominent gas-phase species and particulates at different altitudes in the mesosphere and lower thermosphere. 2) Understanding the rates and mechanisms of reactions of species (of natural and human-made origin) in the mesosphere and lower thermosphere that affect the dynamics, lifetimes, and radiative transfer properties. 3) Development of robust and predictive models of the mesosphere and lower thermosphere that incorporates new knowledge of chemical speciation in the atmosphere and describes the behavior, dynamics, and interaction with materials that might affect space enterprise resiliency.
Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than 8 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Julie Moses, AFOSR, 703-696-9586, julie.moses@us.af.mil; Dr. Michael R. Berman, AFOSR, 703-696-7781, michael.berman@us.af.mil; Dr. Michael Yakes, AFOSR, 703-835-6716, michael.yakes@us.af.mil; Dr. Andrew Sinclair, AFOSR, 703-696-1141, andrew.sinclair.2@us.af.mil.

Topic 2: (AFOSR) Ethical Constructs and Adaptive Learning Systems

Background: The field of Artificial Intelligence (AI) is evolving at an extraordinary pace and has started to have a profound influence on society. The convergence of transformative AI science in generative models [1], classification methods [2], and learning frameworks [3] used in Adaptive Learning Systems (ALS) leads to new forms of Human-Machine Teaming (HMT), creating both challenges and opportunities for the DoD mission. Responsible use of AI is one of the five core tenets of HMT, and a critical research area for the DoD. This implies that there is an urgent need to understand, develop and verify means of implementing ethical principles into AI. The opportunities lie in the convergence of multiple scientific disciplines and disparate viewpoints, which may allow ground-breaking advances in the formulation and interpretation of core ethical principles and factors, which can then potentially bind the AI performance to acceptable ethical behavior, via appropriate measures and norms [6, 7, 8, 9, 10]. The challenges are also formidable, and despite the growing and widespread interest in the problem [4,5], solutions will require foundational scientific research. The problem is also particularly difficult for the DoD, which is faced with an increasing urgency to advance responsible artificial intelligence (RAI) in scenarios of HMT and environments which are intrinsically uncertain, stochastic, adversarial and rapidly changing. A principal feature of the problem is that ethics are a social construct and are not rigorously defined and delimited. Interpretation of ethical principles by an AI calls for new fundamental, mathematical approaches to the problem. Traditional methods of control of autonomous systems may not apply, unless for some trivial scenarios; probabilistic approaches call for large-scale experimentation and data-mining, which is not entirely realistic for defense applications. Ethical theories may be leveraged as guidelines, but these are developed for human society, and we should not assume that ethical concepts in ALS would mirror the human ethical structures. In fact, there is empirical evidence that rationales and perceptions of ethical behavior by humans, versus robots, are different. Thus, one may have to account for the complexity, in HMT, of interpreting ethical behavior by humans and machines in multiple directions (H-H, H-M, M-H, M-M, and clusters…).

This MURI calls for radical approaches and fundamental scientific advances which can potentially lay down the foundation for ethical AI. This research should aim well beyond known questions of bias, fairness and transparency, which are not of interest here. Rather, new approaches need to be developed that allow for the integration of ethical codes that may (and likely will) look different in multiple contexts. These ethical guidelines must be adaptable and transferrable, such that multi-system and lifecycle approach to their assessment and refinement can allow optimization. They must allow rapid decision-making, and be implementable in compact platforms, for autonomous systems of potential use by the DoD. This research should also develop metrics and normative procedures that are tailored to the HMT framework. Of note is the possible need to re-evaluate in this context how to conceptualize and measure risk, as its minimization implies a quantitative metric which may not be well-suited to ethical concepts.

Objectives: The objectives of this research topic are to generate new and fundamental scientific approaches that underpin the incorporation and interpretation of ethical constructs into ALS and allow the development of advanced HMT scenarios where ethical actions can be reliably obtained, evaluated, measured, within the constraints of DoD operations. It should be noted that this call is not limited to the use and modification of current AI architectures and novel approaches and frameworks which have the potential to address the core issues of AI ethics are welcome. Validation is an important and challenging problem, and although this may not be fully executed during the proposed research, approaches to the problem are a factor to consider.

Research Concentration Areas: Suggested areas include but are not limited to the following key areas: 1) development of mathematical concepts that can reliably and efficiently lead to the inclusion, interpretation, and exchange of variable ethical constructs. This includes metrics and measures, towards refinement and optimization procedures; 2) the formulation of ethical theories and/or experiments and data acquisition for all aspects of the HMT framework, compatible with the afore-mentioned mathematical concepts, towards explainability; 3) reinforcement methods, for life cycle and multi-system adaptation and optimization. The proposed research areas should, in combination, address the challenges described in the background section. Potential disciplines to leverage include, but are not limited to applied mathematics, computer science/AI, social science, cognitive science; as well as, potentially, game theory for reinforcement and adaptation, or computational economics for risk assessment. This topic addresses questions that have a profound philosophical context and calls for innovative thinking; all disciplines are welcome if a focused effort can be formulated.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions should be discussed with the topic chiefs during the solicitation's white paper phase.

Topic Chiefs: Dr. Brett Pokines, AFOSR, brett.pokines.1@us.af.mil; Dr. Laura Steckman, AFOSR, laura.steckman.1@us.af.mil; Dr Gregory Ruark, ARO, gregory.a.ruark.civ@army.mil.

References:

1. Tunyasuvunakool, K., Adler, J., Wu, Z. et al. Highly accurate protein structure prediction for the human proteome. Nature 596, 590–596 (2021). https://doi.org/10.1038/s41586-021-03828-1
2. Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "ImageNet classification with deep convolutional neural networks." Communications of the ACM 60.6 (2017): 84-90
3. LeCun, Y., Bengio, Y. & Hinton, G. Deep learning. Nature 521, 436–444 (2015). https://doi.org/10.1038/nature14539

4. Jobin, A., Ienca, M. & Vayena, E. The global landscape of AI ethics guidelines. Nat Mach Intell 1, 389–399 (2019). https://doi.org/10.1038/s42256-019-0088-2
5. Mittelstadt, B. Principles alone cannot guarantee ethical AI. Nat Mach Intell 1, 501–507 (2019). https://doi.org/10.1038/s42256-019-0114-4
6. Ronald C. Arkin, Patrick Ulam, and Brittany Duncan. An Ethical Governor for Constraining Lethal Action in an Autonomous System, Technical Report GIT-GVU-09-02 (2009)
7. Artificial Intelligence Ethical Principles for the Department of Defense, February 2020
8. Responsible AI Strategy and Implementation Pathway, DepSecDef 2022
9. Crowe, Weston-Scheuber, "Principles of International Humanitarian Law", Edward Elgar Publishing, 2013
10. A. D. Ames, X. Xu, J. W. Grizzle and P. Tabuada, "Control Barrier Function Based Quadratic Programs for Safety Critical Systems," in IEEE Transactions on Automatic Control, vol. 62, no. 8, pp. 3861-3876, Aug. 2017, doi: 10.1109/TAC.2016.2638961

Topic 3: (AFOSR) Structured Light for High Field, High Intensity Laser-Matter Interactions

Background: The ability to tailor the physical features of light fields in space and time has proven time and again to open new realms of science and technology and enable new capabilities for basic and applied science. Light possesses many degrees of freedom including amplitude, frequency, polarization (spin angular momentum), and temporal structure. The identification of and control over orbital angular momentum (OAM) via spatial phase structure beginning 30 years ago is a still developing area finding application in fields as diverse as optical communications, microscopy, metrology, beam propagation, and quantum optics [*Journal of Optics*, **24**, 124005 (2022)]. Recent demonstrations exploiting OAM in ultrashort pulse nonlinear optics include the demonstration that high harmonic generation not only preserves OAM but that the OAM of driving beams can be used to tailor the spectral, divergence, and temporal properties of high harmonic produced extreme ultraviolet and soft x-rays radiation [*Science*, **364**, 1253 (2019); *Science Advances*, **8**, eabj7380 (2022)] – properties which are important for applications but otherwise challenging to obtain and control. Second harmonic generation of spatiotemporal optical vortex (STOV) beams was used to demonstrate that individual photons can carry intrinsic OAM modes perpendicular to the direction of propagation. [*Optica*, **8**, 594 (2021)]. Recent theory studies predict that the use of a full Poincare beam at ultra-high intensity leads to efficient production of gamma-rays which also carry OAM [*Physics of Plasmas*, **29**, 093106 (2022)]. Very recently, enhanced neutron flux was demonstrated with an OAM-driving laser at near relativistic intensities with relaxed pulse energy and temporal duration requirements [arXiv:2405.12330]. These results suggest that phase structured light may offer a new knob to influence and enhance high-field, high intensity laser-matter interactions (LMIs), opening both a new window into the basic science of LMI and the ability to impart control over secondary sources of radiation. Laser-driven secondary sources of particle (i.e., electrons, protons, heavy ions, neutrons, etc.) and photon beams (i.e., x-ray, gamma-ray) hold great potential for science and a myriad of technological applications including non-destructive evaluation of a broad array of materials, materials research and manufacturing, radiation hardening and survivability, and medical therapies. However, these secondary sources can be limited in their properties, including flux, energy and energy spread, directionality, and tunability. Novel micro- and nano-structured target samples have demonstrated the potential for enhanced LMI, resulting in enhanced beam properties, improved efficiency and novel effects (such as proton beam focusing [*Scientific Reports*, **10**, 9415 (2020)]). While these results are exciting, complex samples may ultimately limit the ability to exploit future high repetition rate driving lasers for cost effective, high flux particle and photon beams.

It is timely for a multidisciplinary effort to explore the potential of phase structure – in conjunction with light's other degrees of freedom [*Light: Science and Applications*, **11**, 205 (2022); *Nature Photonics*, **15**, 253 (2021)] – to enhance and control high-field, high-intensity laser-matter interaction. Exploiting control over light's many degrees of freedom including novel, non-separable states may offer a path to improved efficiency, enhanced and/or novel secondary radiation beam properties, and operation at or near the repetition rate of the driving laser. Both intra- (i.e. single pulse interactions) and inter-pulse LMIs are of interest (i.e., multi-pulse interactions with pre-structuring/preparation of the sample target by prior pulses, e.g., building on the extensive body of knowledge for laser machining in solids and recent results in imprinting waveguides in air [*Optica*, **15**, 505 (2023)]).

Objective: The objectives of this MURI are: 1) to explore, theoretically and experimentally, the application of phase-structured OAM light for pulsed, high field, high intensity LMI; 2.) to explore, theoretically and experimentally, the application of broadly structured, exotic light states, for high field, high intensity LMI by simultaneously controlling multiple degrees of freedom of light. Both objectives 1.) and 2.) will explore the potential for structured light to reach novel regimes of LMI otherwise inaccessible to a given laser driver. Both objectives will use spatiotemporal-structured light to control LMI at both ultrahigh intensity and power (i.e., $\geq 10^{19}$ W/cm^2 focused intensity or 10 TW peak power) and at more moderate intensities.

Research Concentration Areas: Overarching research areas include: (1) Experimental demonstration of spatiotemporal-structured light including OAM as well as simultaneous control over multiple degrees of freedom at high field, high intensity laser sources. (2) Experimental application of structured light to drive LMI at high field/intensity - Proposing teams should identify specific LMIs and/or secondary sources of radiation of interest. Proposals should demonstrate how selected LMIs/secondary sources of radiation may produce the beam properties required for novel applications. The scaling of average secondary source flux with application-required beam properties is of particular interest. Exploration of the potential for structured light to reach novel regimes of LMI (such as, but not limited to, acceleration mechanisms) not accessible without spatiotemporal structuring is also of key interest. Additional exploration areas of interest include, but are not limited to, performance comparison of spatiotemporal-structured driving lasers with structured target samples (with the goal of reducing demands on sample structure, supporting future operation at native repetition rates) and novel LMI effects leading to enhancements in secondary beam properties important for applications such as particle/photon energy and energy spread, directionality, focusing/intensity, and energy tunability. (3) Modeling and theory of both the novel structured light states and LMI.

Proposing teams should identify how the results of the identified LMIs/secondary sources of radiation may be generalized to more broadly progress the use of ultrafast structured light to control LMI for other applications not explicitly pursued. To address these overarching areas, it is anticipated that teams will demonstrate expertise in and access to: (A) high-field, high-intensity lasers and diagnostics; (B) optical science for OAM generation and general beam shaping to include generation, manipulation, and characterization of structured light with OAM and simultaneous control over multiple degrees of freedom; (C) experimental LMI at ultra-high fields/intensities (including material design and sample preparation, experience with secondary sources of radiation, and associated (rep-rated) diagnostics); (D) modeling and theory of structured light and modeling and theory of LMI at ultrahigh fields/intensities; (E) potential applications of the structured light and of generated particle and photon beams; and, (F) metrology (precision measurements/diagnostics are expected).

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Andrew Stickrath, AFOSR/RTB, 703-696-9551, andrew.stickrath@us.af.mil; Mr. Quentin E. Saulter, ONR/Code 35, 703-696-2594, quentin.e.saulter@us.navy.mil

Topic 4: (AFOSR) Optics with Dynamically Reconfigurable Arrays of Molecules and Atoms (OhDRAMA)

Background: Light-matter interfaces and interactions are ubiquitous and critically important in nature and everyday life, from instances in biology (*e.g.*, vision or photosynthesis) to a myriad of human-made applications. Groundbreaking research on classical metamaterials has revolutionized the technological landscape with innovations such as diffractive optic elements. The recent advent of arrays of coherently controllable ultracold atoms and molecules realized with optical tweezers enables previously inaccessible understanding and exploration of the interactions of fields or photons with quantum matter. The spatial structure of the arrays and the quantum state of the array particles, both individual and collective, can be dynamically configured in a controllable manner, allowing pristinely engineered light-matter interactions that can vary temporally, spatially, and in terms of the internal state of the array particles. Similarly, optical science has led us to novel abilities in realizing light with complex spatio-temporal structure, as well as embodying it with topological properties. The interaction of light and quantum matter both carrying such spatio-temporal, geometric and topological information, could potentially create new physical regimes and open new fundamental research directions. Exploring this rich, combined parameter space can bring new fundamental understanding of light-matter interactions and collective behavior, boundary or bulk effects, and contribute to the development of new materials, including quantum "metamaterials" with properties that can be configured on-the-fly, as well as uncover entirely new phenomena.

There is timely and growing interest in the community to exploit arrays for new fundamental understanding: the geometry of the arrays can be constructed in either one-, two-, or three-dimensions; the geometric patterns can be temporally constant or modified on various and multiple time scales; the array can be comprised of periodic structures or irregular ones (*e.g.*, random, lattice, tree-like, frustrated, etc.) and be either homogeneous or heterogenous in terms of the particles/species in the array; finally, each particle in the array can be configured in an arbitrary coherently controlled quantum state, and some or all particles can share the same state. Likewise, the impinging electromagnetic fields of interest can vary spatially and temporally, can have a wavelength that is smaller or larger than the array spacing, or have information encoded in various degrees of freedom such as polarization or angular momentum, or encode knot-like structure. Together, this vast space of allowable and precise configurations of quantum particles and fields empowers DoD-relevant explorations of novel quantum states of matter, and creation and manipulation of complex quantum information. By temporally modifying the coupling parameters, the structured light field can temporally (adiabatically or not) imprint its structure onto the quantum matter and induce states and dynamics never realized before. The response of the atomic arrays is therefore of key interest and must be monitored with precise diagnostics. This response may include the generation of photonic fields with new properties and unusual quantum correlation structures. This can have profound implications for the generation and transmission of highly complex and structured quantum information.

Objective: The MURI Topic aims to discover and explore new many-body phenomena or new ways to dynamically manipulate arrays of molecules and/or atoms interfacing with electromagnetic fields with complex spatio-temporal structure. For such light-matter interaction, the structure of the arrays is envisioned to be – spatially and/or temporally - dynamically reconfigurable, with individual coherent control of each particle in the array. A mixture of theoretical and experimental work in some combination of optics, quantum information science, metamaterials, and atomic and molecular physics is envisioned. Although new, enabling models and concepts with no current analogs may be in scope, quantum computing or simulation are not an intended target of this topic.

Research Concentration Areas: We seek significant improvements to the state of the art or novel capabilities. Some directions for exploration can be, but are not limited to, 1) cavity-QED with reconfigurable, coherently controllable cavity boundaries, and interfacing quantum particles with the modes of such cavities; 2) optical coupling of atomic array with structured light and design and exploration of coupling mechanisms; 3) encoding, manipulation, and readout of quantum dynamics and information with the proposed systems; 4) study of configurations leading to chosen potential applications, for example dynamically reconfigurable quantum "metamaterials", new quantum information states, or other collective behaviors. This list is neither exhaustive nor a recommendation for the directions of research.

Anticipated Resources: Potential awards under this topic will not exceed $1.5M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chiefs during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Boyan Tabakov, AFOSR, (703) 696 9518, boyan.tabakov@us.af.mil; Dr. Grace Metcalfe, AFOSR, (703) 696 9740, grace.metcalfe@us.af.mil; Dr. Arje Nachman, AFOSR, (703) 696-8427, arje.nachman@us.af.mil

Topic 5: (AFOSR) 2D/3D heterostructures via remote epitaxy

Background: Remote epitaxy is a recently developed synthesis process that opens the potential possibility of scalable lift-off of single crystal membranes from the substrates. The key innovation is placing thin layer of van der Waals (vdW) material, typically graphene, within an epitaxial growth. This vdW material is reported to have two functions: 1) allowing the permeation of substrate potential which promotes a high quality epilayer grown epitaxially with the substrate; 2) permitting the development of uniform lift-off of membranes from single crystal substrates thanks to the weak bonding force relative to the substrate and grown film. Initial demonstrations have shown promise for synthesizing and exfoliating high quality single crystal membranes of a wide range of materials, including GaAs, GaN, complex oxides and intermetallics. Freestanding single crystal membranes have different characteristics from their bound thin film counterparts, yet the fundamental limits of the remote epitaxy technique are not yet understood. Without the clamping from the substrate, these membranes are strain free and can withstand extreme elastic strains. The mechanism for membranes to sustain large elastic strain is not well understood fundamentally and has been used to modulate physical phenomena such as magnetism and superconductivity in quantum materials that have been not predicted by first principles calculations. Since the resulting films can be grown with arbitrary thickness and stacked with other materials without the constraints of the lattice match and chemical compatibility, a new class of mixed 2D/3D heterostructures can be enabled in nearly unlimited

combinations. This can lead to unprecedented degrees of freedom to synthesize heterostructures and unlock new optical, electronic, and other physical properties.

The underlying mechanism for promoting remote epitaxy remains an active research topic, particularly regarding the role of interfaces between single crystal membrane, vdW layer and substrate. For example, both pinholes in graphene and the crystal field of vdW material itself have been demonstrated experimentally to promote epitaxial growth and resulted in single crystalline films that can be easily lifted off from the substrates. It is thought that these pinholes serve as nucleation sites which seed the resulting growth. Meanwhile, the experimental observations in other reports can only been explained through the "remote" interaction through the vdW layers. Furthermore, the roles of other imperfections such as debris, step edges, and dislocations on both the resulting film quality and its optoelectronic properties have not been fundamentally understood. This topic addresses the critical question of how general or selective remote epitaxy is for the combination of materials, vdW layer, underlying substrate, and the growth conditions, before we can widely adopt it for making heterostructures of materials of various dimensionality. If successful, this effort will not only advance our fundamental understanding of the mechanisms promoting high quality heterogenous integration via remote epitaxy, but also exploit the unique advantages of free-standing single crystal membranes for enabling a new class of heterostructures with new physical properties and emergent functionality. If adopted widely, the lift-off of freestanding single crystal membranes could have an additional benefit of significant cost savings for manufacturing of integrated microelectronic devices, especially for non-silicon single crystal substrates, which are often orders of magnitude more costly than that of silicon.

Objective: The goal of this topic is to elucidate the roles of defects and interfaces in the epitaxial growth of 3D crystal membranes on graphene or 2D material templates, and to demonstrate integration of dissimilar materials into heterostructures with multifunctional and emergent physical properties.

Research Concentration Area: Research concentration areas include, but are not limited to the following areas: (1) Elucidate the role of interfaces for promoting epitaxial growth with regard to the nucleation/growth mechanism of 3D membranes; (2) Develop fundamental understanding of interfacial interactions between substrate and membrane, focusing on the exfoliation process and the role of defects in both the growth and exfoliation; (3) Demonstrate and optimize assembly processes of 2D and 3D heterostructures, and characterize the resulting microstructure and electronic properties associated with the 2D/3D interfaces; (4) Modeling and experimental validation of 2D and 3D heterostructures with physical phenomena that are unique to these heterostructures.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Michael Yakes, AFOSR, 703-835-6716, michael.yakes@us.af.mil; Dr. Jiwei Lu, AFOSR, 703-835-6515, Jiwei.lu@us.af.mil.

Topic 6: (ARO) Fungalphabet: Deciphering the Hidden Language of Fungal Networks for Environmental Intelligence

Background: Mycorrhizal fungi are soil fungi that form symbiotic relationships with the roots of plants. A defining feature of mycorrhizal fungi is their mycelium—a vast network of rootlike filaments—which gives structure to soil and facilitates the transport of nutrients, bacteria, and other exudates, as well as electrical signals across the soil environment. Beyond providing this scaffold for mass and energy transport and signaling, mycorrhizal fungi synthesize a diverse array of volatile organic compounds (VOCs) that diffuse through soils and the atmosphere and themselves serve as signals for long-distance intra- (and inter-) species communication. In fact, VOC-mediated signaling commonly initiates the use of mycelial networks as a "superhighway" for information transport, resource allocation, and threat response.

Understanding the complex interplay between VOCs and mycelial networks has the potential to enable precise control over and interrogation of mycorrhizal fungi for advanced environmental sensing. Fungal VOC profiles, comprising diverse and complex chemistries, reflect the environmental conditions a fungus is experiencing. Thus, characterizing the fungal "volatilome" and attendant (electro)chemical responses through the mycelial network will generate a deep understanding of subterranean conditions. It is conceivable that those signals could be intercepted and translated by sampling strategies, which may be atmospheric or geophysical, for passive and/or remote environmental monitoring. An ability to manipulate and control specific VOC profiles or (electro)chemical signals to interface with mycelial networks and modulate their behavior could further enable environmental responsiveness such as concentrating compounds of interest for remediation, resource extraction, and carbon storage; crop protection; and real-time, covert signal transmission and transduction.

Recent advances in fungal genetics and molecular biology are revealing the myriad metabolic pathways involved in VOC production. However, foundational biogeochemical research is still needed to characterize the coupled or interactive environmental factors that govern VOC fluxes through soil and into the atmosphere. Similarly, there is a need to explore how mycorrhizal fungi control and propagate electrical and chemical signals across their large and complex mycelial networks, and to characterize patterns and thresholds of response to complex environmental stimuli. New capabilities in porous materials, soft/bio-hybrid/bio-tronic materials, and synthetic biology tools are needed to investigate the functional properties of fungal biomaterials, capture and transduce (electro)chemical signals, and ultimately translate the "language" of fungal networks to yield new fundamental understanding of the biological components and processes involved in sustaining living bionetworks. Results and insights gained from such a coupled environmental-biological-materials engineering approach may ultimately provide the ability to control mycelial network responses, enabling new capabilities such as signal transmission guided by external electromagnetic fields or microencapsulated-VOC messengers.

Objective: Elucidate the genetic and biogeochemical mechanisms responsible for fungal VOC production and consumption; understand the relationship between the volatilome and coordinated flows of mass and energy through mycelial networks and to translate the meaning of these signals; and use this understanding to engineer interfaces to living fungal systems for interpretable signal transduction. Recognizing the vast array of VOCs and signals, proposers should plan to identify a subset of VOC and/or (electro)chemical signals, with the goal of extending to other signals in the long term.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) Devise appropriate materials- and/or chemistry-based approaches (e.g., new porous materials) to capture and characterize the fungal volatilome in the atmosphere and within soil; (2) Elucidate the biochemical and genetic pathways responsible for distinct fungal VOC patterns in mycorrhizal fungi; (3) Characterize and model the relationships between the fungal volatilome, with a focus on understanding the interactive

effects of dynamic environmental conditions (e.g., temperature, humidity, UV); (4) Concurrently, explore how mass (e.g., nutrients) and energy (e.g., electric or acoustic signals) move through adaptive, complex networks, with a focus on understanding fungal growth architectures and the speed and directionality of information flow; and (5) explore soft matter/bio-hybrid approaches to directly interface with fungal networks to characterize (electro)chemical signal transmission through space and time.

Anticipated Resources: No more than $1.5M per year for five (5) years, supporting no more than six (6) faculty researchers. Exceptions should be discussed with topic chief(s) during the white paper phase.

Research Topic Chiefs: Dr. Liz King-Doonan, ARO, elizabeth.k.king-doonan.civ@army.mil, (919) 549-4386; Dr. Evan Runnerstrom, ARO, evan.l.runnerstrom.civ@army.mil, (919) 549-4259

Topic 7: (ARO) Evolving Chemistry and Biology to Degrade Polymers with Stable Chemical Bonds

Background: Polymeric materials find utility in a broad range of applications because they are highly tunable and durable but revalorizing them for other applications is very challenging. Chemical and biological approaches have been investigated to make polymers easier to degrade or depolymerize, but these often target labile bonds such as esters, urethanes, or carbonates. A variety of individual enzymes have been evolved to degrade natural and synthetic polyesters such as poly(ethylene terephthalate) but there is currently a lack of efficient biological approaches to breaking inert chemical bonds often found in polymers with high thermal, mechanical, or transport performance. Several organisms have been identified that can partially degrade polyethylene (PE) or fluoroalkyl substances but do so at very slow kinetics. Previous synthetic approaches to make these types of polymers more degradable introduce labile chemical bonds to facilitate breakdown which may limit performance in demanding applications or long-term durability. Little effort has been devoted to designing the materials to facilitate uptake and breakdown or evolving the biology to increase degradation rates and compatibility between dissimilar polymers and biological entities.

We envision a concerted, synergistic and highly multidisciplinary effort to converge polymer design with microbial evolution toward the challenging direct breakdown of strong chemical bonds such as C-C and C-F to better valorize PE, fluoropolymer, or other impervious carbon sources to useful chemical feedstocks. Microbes such as bacteria and fungi are efficient at assimilating and metabolizing polymers with labile chemical bonds but are still relatively slow at breaking down more thermodynamically stable bonds. There is also limited understanding of the microbial and enzymatic mechanisms underlying biodegradation. Furthermore, microbes and the enzymes that they encode rarely act alone; these microbes exist as functional consortia and little is known about how communities of microbes and their enzymatic activities can better facilitate efficient degradation. Beyond that, identifying genetic variants that lead to degradative abilities will be crucial to not only enzyme design but can also inform polymer design based on expected enzymatic machinery. Consortia of microbial species should be sufficiently promiscuous to act upon polymers with different backbone chemistry or side chain functionality for decomposing mixed waste streams. For more challenging substrates, higher temperatures and/or organics solvents may be needed to increase chain mobility and conformational accessibility within highly crystalline or crosslinked systems to facilitate breakdown. These harsher environments may denature enzyme conformational structures needed for degradative catalytic activity. To mitigate this, the broad functional diversity of bacteria and fungi present in extremophilic and polyextremophilic environments can provide

the inspiration to evolve toward the required enzymatic activity within non-native and complex environments.

Objective: Accelerate the decomposition of recalcitrant polymers without sacrificing performance attributes by identification of genetic, metabolic, and enzymatic pathways and mechanisms for polymeric degradation among bacterial and fungal consortia and utilizing that information for iterative improvements in polymer design and more efficient and evolved microbial activity.

Research Concentration areas: Suggested research areas include but are not limited to: (1) Data-informed design of polymers that better interface with bacteria and fungi and present credible breakdown pathways without introducing labile bonds and sacrificing performance (2) Application of omics based approaches and high resolution structural biology to select for consortia of fungal or bacterial species and their enzymes capable of depolymerization (3) Utilization of computational biology, directed evolution, protein engineering, deep learning or other methods to evolve enzymes/organisms to breakdown emergent polymer designs (4) Development and advancement of genetic tools to unmask function of novel degradative gene products (5) Engineering *in vivo* and *in vitro* platforms to enable microbial consortia and/or groups of enzymes to affect efficient degradation in a spatial and temporal manner (6) *In silico* design and synthesis of artificial metalloenzymes to break C-C, C-F and/or other non-labile bonds.

Anticipated Resources: No more than an average of $1.50M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with topic chief(s) during the white paper phase of solicitation.

Research Topic Chiefs: Dr. Robert Lambeth, (240) 499-6692, robert.h.lambeth2.civ@army.mil; Dr. Robert Kokoska (919) 549-4342, robert.j.kokoska2.civ@army.mil; Dr. James Berry (240) 941-7298, james.f.berry49.civ@army.mil

Topic 8: (ARO) Space-time Metamaterials for Multi-dimensional Wave Transformation

Background: In crystalline materials, spatially periodic arrangements of building blocks induce a band structure with energy band gaps: these energy gaps dictate which wave frequencies can or cannot propagate through the crystal. In contrast, a temporally periodic material (i.e., a material in which an external drive periodically modulates its physical properties) features momentum gaps in its band structure. The existence of a momentum gap in such a material carries profound implications - waves of any frequency and phase with a k-vector in the momentum gap couple to the external drive and are exponentially amplified without bounds. Combining spatial and temporal periodicities in a single material would enable band structures with band gaps in both energy and momentum. Such materials would even support mixed or hybrid momentum-energy gaps, allowing unprecedented wave behaviors and manipulation. For example, all properties of a wave (amplitude, frequency, wavefront shape, etc.) could be rapidly and efficiently transformed over broad bandwidths without needing resonance or phase-matching, enabling functionalities such as frequency mixing, spatio-temporal nonreciprocity, angularly selective nonreciprocal transmission, and more. Particularly intriguing are the recent experimental observations of reflection/refraction (i.e., coherent wave reversal or change in direction) at time interfaces, interference between time-reflected and time-refracted waves, and spectral diffraction from temporal double slits enabling amplification or absorption of broadband signals. Contemporary advances in photonic metamaterials design suggest that novel engineered materials with such unique functionalities are within reach.

Real-world embodiments of these so-called space-time metamaterials (STMMs) would open a new scientific frontier for wave transformation (from radio-waves to light and sound), provided that certain critical scientific questions are answered. Specifically, a generalized mathematical framework is needed to rigorously characterize linear and non-linear responses of STMMs. STMMs will require new simulation and design tools that account for the extreme structural and temporal complexity of space-time-variant systems. Materials design and fabrication will be needed to discover, create, and manipulate stimuli-responsive materials (e.g., epsilon-near-zero or fs-scale phase change materials) that can be modulated at relevant time scales, and fabricated into metamaterials at relevant length scales. New methodologies will be needed to experimentally measure and characterize STMMs' response in the near- and far-field. New physical models are needed to fully understand how nontrivial modulation dynamics interact with anisotropy, gain/loss, and nonreciprocity, and to probe fundamental mechanisms and limits for frequency conversion and phase conjugation. A comprehensive, multidisciplinary research effort would lead to a generalized theory of spatio-temporal dynamics of novel STMMs with unprecedented functionalities enabling a new paradigm for extreme control of wave responses (frequency, energy, direction, amplification, nonreciprocity, etc.).

Objective: This topic seeks a theoretical, computational, and experimental framework with which to design, model, create, understand, and dynamically manipulate new space-time metamaterials enabling multi-dimensional wave transformation over broad bandwidths with maximized efficiency.

Research Concentration Areas: This MURI will bring together researchers in mathematics, physics, materials science, optical and acoustic engineering. Specific research topics include: 1) Rigorous mathematical treatment of space-time-varying interactions in periodically driven systems, accounting for nonreciprocity, anisotropy, nonlinearity, gain/loss, etc.; 2) Computational tools to design and simulate STMM platforms with tunable composition and structure; 3) Materials design and fabrication approaches for time-modulable metamaterials with complex multiscale architectures; 4) Elucidation of underlying mechanisms of newly observed phenomena; 5) Exploitation of STMM for frequency manipulation, space-time diffraction, broadband phase conjugation, distortion compensation, and/or other operations relevant in engineering settings.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than 6 funded faculty researchers.

Research Topic Chiefs: Dr. Tania Paskova, (919) 549-4334, tania.m.paskova.civ@army.mil; Dr. Evan Runnerstrom, (919) 549-4259, evan.l.runnerstrom.civ@army.mil; Dr. Arje Nachman, (703) 696-8427, arje.nachman@us.af.mil.

Topic 9: (ARO) Altermagnetic Topology

Background: Altermagnets (AM) have recently been put forward as a third fundamental kind of collinear magnetism in addition to ferromagnets (FM) and antiferromagnets (AFM). It has alternative spin arrangements similar to AFM, but also exhibits spin splitting as in FM due to a distinctive interplay of spin arrangements and crystallographic symmetries. As a result, AM shares some common properties with both FM and AFM. But more importantly, AM also has unique properties that are unparalleled in either FM or AFM because of the coupling of AM with crystallographic topology, resulting in Berry phase and topological change in electronic band structures with zero net magnetism, lifting of Kramers

degeneracy, and alternating spin-polarized pattern of Fermi surface. Non-trivial topological features in AM can lead to unique electrical transport and magneto-optical responses such as quantum anomalous Hall effect (QAHE) without net magnetization. Furthermore, as the spin splitting and magnetic interaction energy scale can be on the order of electron-volts, these exotic states can potentially be realized at or above room temperature. Along with spin splitting that breaks Kramer's degeneracy, an AM also has degeneracy preserving band crossings at symmetry-enforced points of the Brillouin zone. These crossings are predicted to be rich in Weyl physics and the associated topological magnetic phase transitions such as Weyl cone annihilation that are distinctly different from those by electronic topology alone. They serve as natural sources for both Berry curvature, a quantity encoding the geometric properties of the electronic wavefunctions in a solid, and quantum geometry. Previously perceived as conventional AFMs, the realization of AM represents a significant departure from past understandings of magnetism; study of the rich and exotic electronic phases that naturally result from materials hosting AM spin textures could help reveal their topological nature.

Experimental confirmation of AM spin splitting has recently been demonstrated using X-ray angle-resolved photoemission spectroscopy (ARPES) in RuO_2 and MnTe systems. Since it relies on interactions with the crystal field, rather than spin-orbit coupling, an AM does not require heavy lattice atoms. This significantly expands materials search landscape. A variety of metallic, insulating and semiconducting AM candidates have been predicted. If experimentally realized, these AM materials promise to enable capabilities like controlling spin currents without dissipation and without an external magnetic field. In addition, proximity induced new superconducting states such as spin-triplet and topological superconductivity could also be realized. These insights have potential to open an entire new field of magnetic textures based on AM.

This topic aims to realize these topological states enabled by symmetry-dependent rules to establish AM as a platform in which the confluence of magnetism, topology, and quantum geometry may be studied simultaneously to create unique and innovative electronic and magneto-optical device concepts capable of operating at room temperature. To accomplish the stated goal, a multidisciplinary approach including materials science, chemistry, physics and electrical engineering is needed.

Objectives: To investigate the interplay between AM and crystallographic topology to identify novel topological and correlated magnetic states at zero net magnetization with the goal of bringing these states to room temperature or higher.

Research Concentration Areas: Suggested research areas of interest include but are not limited to 1) Theory driven materials design and discovery; 2) Material growth and synthesis; 3) Theoretical predictions of AM topological phenomena; 4) Experimental characterization techniques, including thermodynamic probes, electrical transport, and spectroscopy, etc.; 5) Novel electronic and photonic device concepts leveraging AM topological states.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions should be discussed with the topic chiefs during the white paper phase.

Research Topic Chiefs: Mahesh Neupane, (301) 467-0782, mahesh.r.neupane.civ@army.mil; Tom Oder, 240-967-1218, tom.n.oder.civ@army.mil

Topic 10: (ARO) Ontology Engineering for Machine Learning in Open-ended Sensor, Model, User Systems

Background: In classical federated learning, a central hub broadcasts the parameters of its model to edge devices ("nodes"). These acquire local data (via sensors) and fine-tune the model (via edge compute resources), then transmit data and updates back to the hub, which aggregates them to update the central model. This requires substantial edge compute and bandwidth; additionally, local data is assumed to follow the same distribution.

Modern methods are limited in the type of inter-node communications they can accommodate. Nodes cannot share data in different modalities or from different distributions without first "translating" it, potentially slowing the system's response to changing conditions and generating errors. Machine learning relies on models that are universal function approximators, leading to extremely high costs in power and time required to train; and representations shared between nodes may not have desirable properties such as utility, informativeness, complexity, compactness, robustness to attack, etc.

It is nontrivial to optimize a model over the simplex (generally, a polytope) characterizing tradeoffs between these properties. It is also nontrivial to ground, or embed, distinct models, with very different data modalities, in the same conceptual space – especially if the set of modalities is *open-ended,* i.e., able to incorporate previously unseen data types. A desirable feature would be semantic grounding, which is rare in modern machine learning: representations are often model-specific, and communication format is arbitrary and limited, e.g., transmitting some simple operation on the model's latent space. Most existing approaches to the problem are specific to natural language (e.g., semantic graphs based on LLMs or computational linguistics). We lack a framework to understand relationships between heterogeneous representations and communication between components in a large, open-ended system or set of systems. In contrast, humans map information from arbitrary sources into a useful representation (the "mental model"), subject to basic rules such as causality, logic, and physics. We can identify an object across multiple views, synchronize events, make cross-modal predictions, etc. Critically, we can also efficiently communicate new information using an ontology (e.g., language, mathematics, musical notation) suitable to the task at hand. In information science, formal top-level ontologies have been developed to support broad semantic interoperability between domain-specific ontologies and concepts, with applications ranging from defense and security, supply-chain management and manufacturing, industry standards, medicine, scientific research, etc.

Objective: Create a flexible machine learning framework for embedding data, processes, models, and representations into a shared ontology for principled modeling and efficient communication under complex constraints. Develop techniques to solve the resulting non-convex, multilevel optimization problem over design features and characterize the resulting ontological structure.

Research Concentration Areas: Suggested research areas include, but are not limited to: **(1)** semantic grounding methods to assemble domain-specific ontologies from heterogeneous, multimodal data; **(2)** embedding these domain-specific ontologies into a shared, semantically meaningful space characterized by an upper-level ontology; **(3)** multilevel optimization over the design features of a useful ontology in this space; **(4)** designing new machine learning algorithms to function in this space; **(5)** characterizing the ontology's components and properties. We expect the need for contributions from linguistics, cognitive science, mathematics, ontology engineering, computer science (including computational linguistics and machine learning), and physics.

Anticipated Resources: No more than an average of $1.50M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of solicitation.

Research Topic Chiefs: Dr. John S. Hyatt, (240) 309-8380, john.s.hyatt11.civ@army.mil.

Topic 11: (ARO) Entanglement Engineering with Holographic Duality

Background: Duality principles in physics generally connect descriptions of the same complex system between two different physical instantiations. A more modern version, Holographic duality (HD), is a mathematical concept that maps between two representations of a complex physical system and its interactions, with one representation residing on the boundary of a higher dimensional space of the other. This concept originated with the string-theoretic AdS/CFT correspondence [1], enabling insight into quantum gravity and strongly coupled quantum systems, physical regimes which are for the most part poorly understood, and for which calculations are often intractable. In this correspondence, the classical gravitational curvature of space-time encodes the entanglement structure of the lower-dimensional, strongly correlated quantum system on the boundary. Historically, these ideas have been studied theoretically, using for example formalisms such as the Sachdev-Ye-Kitaev model and Tensor Network States methods, and have been difficult to realize experimentally [2].

Recent experimental demonstrations in atomic, superconducting circuit, and photonic systems provide a new avenue to investigate simulations of complex quantum systems in a dual space. In some cases, limited HD models have been demonstrated and proposed in experiments [3-5]. In others, new experimental techniques for creating synthetic dimensions [6-8] may enable the creation of a holographic dual space useful for entanglement engineering. These exciting new methods could be used to probe entanglement in synthetic matter and test the validity of HD models in those systems. This might offer insights into highly correlated quantum matter such as high-Tc superconductors, strange metals, and other phases yet to be found. Recently, HD concepts have also been applied to quantum information tasks such as quantum error correction (QEC) [9,10]. While QEC itself is not of interest to this topic, investigating how HD can inform our understanding and manipulate information within quantum systems is of interest. Furthermore, extending HD techniques to quantum information tasks such as quantum sensing and metrology is another interesting avenue to explore. Coming from another direction, these models may provide insight into information scrambling and decoherence processes in quantum systems [11]. Both the creation of entangled states and understanding the loss of entanglement are crucial for next generation quantum information, quantum sensing, quantum metrology, and quantum materials and devices. Building experimental tests of the HD framework would also open new avenues in the fundamental physics studies of quantum gravity.

Objective: The goal of this topic is to bring the HD framework for strongly correlated matter and quantum information theory to experimental platforms. The topic seeks to test connections with synthetic matter and exploit experimental methods for HD. The insights so derived should inform our understanding of entanglement in these systems and offer novel models and paradigms for quantum materials, sensing, and/or metrology.

Research Concentration areas: Potential areas of research include, but are not limited to: 1) investigate highly correlated matter using HD and representative algebras; 2) develop protocols to emulate relevant HD models on experimental platforms; 3) investigate the utility of emerging experimental tools to the HD

framework and the potential for these new capabilities to improve our understanding and control of entanglement in quantum matter and systems; and 4) experimentally investigate the potential advantages of HD models for quantum information topics such as scrambling, quantum sensing, and/or metrology.

Anticipated Resources: No more than an average of $1.50M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with topic chief(s) during the white paper phase of solicitation.

Research Topic Chiefs: Dr. Margaret Shea, (240) 941-4880, margaret.e.shea6.civ@army.mil; Dr. Radhakrishnan Balu, (301)-394-4302, radhakrishnan.balu.civ@army.mil

References:
[1] Ramallo, A. V. "Introduction to the AdS/CFT correspondence." arXiv:1310.4319 (2013).
[2] Hartnoll, S. A., *et al.* "Holographic quantum Matter." arxiv:1612.07324 (2016).
[3] Periwal, A., Cooper, E.S., Kunkel, P. *et al.* "Programmable interactions and emergent geometry in an array of atom clouds." *Nature* **600**, 630–635 (2021).
[4] Cooper, E.S., Kunkel, P., Periwal, A. *et al.* "Graph states of atomic ensembles engineered by photon-mediated entanglement." *Nat. Phys.* **20**, 770–775 (2024).
[5] Bienias, P. *et al.* "Circuit quantum electrodynamics in hyperbolic space: from photon bound states to frustrated spin models." Phys Rev. Lett. **128** 013601 (2022).
[6] Luqi Yuan, Qian Lin, Meng Xiao, and Shanhui Fan, "Synthetic dimension in photonics," Optica 5, 1396-1405 (2018).
[7] Chu, A. *et al.* "Photon-mediated correlated hopping in a synthetic ladder," Phys. Rev. Research. **5** L022034 (2023).
[8] Chen, T., Huang, C., Velkovsky, I. *et al.* Strongly interacting Rydberg atoms in synthetic dimensions with a magnetic flux. *Nat Commun* **15**, 2675 (2024).
[9] Steinberg, M., Feld, S. & Jahn, A. "Holographic codes from hyperinvariant tensor networks." *Nat Commun* **14**, 7314 (2023).
[10] Bentsen, G. *et al.* "Approximate quantum codes for long wormholes." arXiv:2310.07770 (2023).
[11] Touil, A. and S. Deffner. "Information scrambling – a quantum thermodynamic perspective." arXiv:2401.05305 (2024).

Topic 12: (ARO) Curved Electromagnetic Propagation

Background: In RF and microwave frequency bands, electromagnetic waves can effectively curve around obstacles through diffraction. At higher frequencies (millimeter-wave through optical), diffraction is minimal because the wavelengths are small compared to common obstacles, therefore casting shadows behind the obstacles. Line-of-sight blockage is a major limitation for communications at these frequencies.

It is possible to create beams that curve as they propagate. Such beams are usually referred to as self-accelerating, since their center seems to follow a nonlinear path, accelerating perpendicular to the initial beam direction, despite the absence of external forces acting on the moving photons. Airy beams, discovered as solutions to the Schrödinger equation, were quickly extended to electromagnetics as a solution to the Helmholtz equation. Airy beams exhibit features such as shape-preserving diffraction-free, and self-healing propagation, i.e., they tend to reform or reconstitute themselves behind an obstacle. Non-paraxial self-accelerating beams with Bessel, Mathieu and Weber function beam shapes have been

predicted with arbitrary trajectories. Self-accelerating beams (SABs) like Airy beams have been demonstrated in the optical part of the spectrum and used in applications such as microscopy, particle manipulation and laser machining. Since SABs can only be realized in the near field Fresnel zone of a radiating aperture, given by 2D^2/λ, where D is the aperture size and is the wavelength, the ranges of optical SABs are limited and must be increased significantly to realize non-line-of-sight communications. New advances in large-scale large-aperture meta-arrays or meta-surfaces (~10s of centimeters) at the sub-THz frequencies (100-1000 GHz) can extend ranges of SABs to hundreds of meters. A proof-of-principle experiment of curving THz wireless data links using self-accelerating Airy beams has been successfully demonstrated.

A new approach for vector beam bending via a polarization gradient instead of amplitude and phase profiles as in Airy beams was recently demonstrated. Unlike the Airy beams, it is the centroid of a vector beam that accelerates rather than the center of intensity of a particular lobe. This new mechanism also suggests that structured light beams with unique orbital angular momentum (OAM) and spin angular momentum (SAM) as well as other unique topological features could be exploited for creating and controlling curved electromagnetic propagation, potentially with improved bending and extended ranges. Understanding of these new effects will require concepts beyond standard electromagnetic theory, such as Lagrangian dynamics and coordinates, Stokes analysis of polarization transformations, and Pancharatnam-Berry phase. The use of distributed and networked arrays may also provide additional degrees of freedom for spatiotemporal control of curved electromagnetic propagation.
Objective: Create fundamental understanding of self-accelerating curved electromagnetic propagation both theoretically and experimentally; exploit its unique features for potential uses in communications, sensing and directed energy.

Research Concentration areas: Suggested research areas include but are not limited to: (1) Theory of SABs for explaining their properties, propagation behaviors and discovery of new types of SABs; (2) Experimental realization and hardware for generation, transportation, detection and characterization of SABs; (3) Use of SABs for information transmission and the effects of their unique properties on modulation and multiplexing; (4) Unique network architectures, including spatially distributed and networked arrays , and protocols for connecting large number of communication nodes with curved directional SAB links; (5) Innovative use SABs for sensing and directed energy.

Anticipated Resources: No more than an average of $1.50M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with topic chief during the white paper phase of solicitation.

Research Topic Chief: Dr. Robert Ulman, 919-225-0468, robert.j.ulman.civ@army.mil**;** Dr. James Joseph, 919-549-4213, james.a.joseph30.civ@army.mil.

Topic 13: (ARO) Optimized Photonic Inference Systems

Background: Significant progress has been made in the design and fabrication of novel photonic structures that employ subwavelength features to arbitrarily shape the electromagnetic field. Historically, flat optics have suffered from poor efficiency, but recent engineering advances have enabled multi-layer or volumetric nanophotonic structures with feature sizes under $\lambda/10$ that can perform optical functions with near perfect efficiency [1]. What's more, multiple optical functions can be achieved in a single structure [2]. In conjunction with a sensing plane, these nanophotonic structures enable a host of passive

sensing operations (e.g. spectroscopy, depth detection, polarimetry), and when combined with processors, facilitate optical inference tasks such as image classification or vision aided navigation. Algorithm and photonic structures are normally considered separately, however photonic structure and algorithm co-design have found superior configurations [3]. Advanced second-order optimization methods currently being explored in the context of robotics and autonomous systems may push this frontier even further [4]. In many cases, these methods outperform the state of the art in finding optimal solutions while simultaneously exploring a broader solution space [5].

Inverse methods that are commonly employed in meta-optic design produce non-convex solutions that are intrinsically non-optimal as local minima pervade the solution space. Historically, investigators have relied on adjoint optimization methods to navigate these complex parameter landscapes, and the power of emerging optimization approaches is under-explored in the field. Even before optimization, there is a clear need for streamlined modeling with nonlinear, nonlocal, or non-trivial influences efficiently captured; simulating the full wave Maxwell's equations for relevant systems can easily lead to multi-day design runs for a single structure. Computational methods on their own offer limited physical insight, and worse, optimal bounds are not known. Physics-based, analytic and semi-analytic approaches are required here to identify benchmarks, tradeoffs, and system constraints [6]. Armed with this information researchers could quantify performance, select ideal materials, set fabrication tolerances, and determine appropriate optimization schemes. A holistic approach combining analytic methods, smart optimization, and novel simulation approaches is required to fully address all these challenges.

Objective: The objective of this MURI is to establish new theories and tools to model and rapidly design nanophotonic systems featuring nonlinear influences that can solve complex problems.

Research Concentration Areas 1. Employ analytic methods to provide optimal bounds and physical insight into nanophotonic structure performance; 2. Demonstrate increased performance through co-design of photonic structures and computational algorithms; 3. Provide experimental demonstrations exploring novel nanophotonic materials fabrication and synthesis and emerging understanding of quantum, nonlinear or nonlocal effects. 4. Deploy optimization schemes or deep learning algorithms with intuition concerning the nature of the solution space to provide verifiably pareto optimal nanophotonic designs; 5. Develop and employ state of the art, efficient EM solvers.

Anticipated Resources: No more than an average of $1.50M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with topic chief during the white paper phase of solicitation.

Research Topic Chiefs: Dr. James Joseph, 919-549-4213, james.a.joseph30.civ@army.mil; Dr. Dean Culver (919) 549-4225 dean.r.culver.civ@army.mil

References:
[1] *Nanophotonics*, 11(10), 2381-2387 (2022) [2] *Nat Commun* 14, 2768 (2023). [3] *Opt. Express* 30, 28358-28370 (2022) [4] arXiv:2409.11649v2 [5] arXiv:2409.04644 [6] *Phys. Rev. Lett.* 125, 263607 (2020)

Topic 14: (ONR) Evaluation and Monitoring of Large-Scale Generative AI

Background: Large-Scale Generative AI models (for short gen-AI) such as the ChatGPT and Diffusion Models took the world by storm. They are powerful, they are everywhere, and they are clearly disruptive. But how robust are they, and more importantly can we trust them? It turns out that gen-AI models are quite unreliable. The same model that can generate astonishing results can also generate the most disappointing and embarrassing results. Perhaps much more dangerous is when the model generates results that look perfectly fine and even 'supported' by scientific papers but are made up or 'hallucinated'.

Typically, AI models (e.g. supervised Machine Learning models) are evaluated by comparing their outputs against the ground-truth data. What makes evaluation of generative AI models difficult is the lack of ground-truth data. An added difficulty for large scale generative models is the randomness in their output: for the same input, they produce different outputs. Consequently, training a gen-AI (pre-training, and fine-tuning), requires extremely large amounts of data and computing power, is very slow and relies heavily on human feedback, which opens numerous problems including the scalability. In addition, instructions and feedback provided by humans are very subjective and create biases, accidental or deliberate. Recent work [1] is addressing some of these problems but finding the right amount of human supervision and feedback is still an open challenge. Most importantly, only a handful of companies have enough resources to engage a sufficiently large number of human evaluators and the whole process is not very transparent.

Gen-AI capabilities often reach and sometimes even exceed human performance or appear to do so. It is easy to envision that very soon some of the gen-AI solutions might be beyond human capabilities to comprehend them (i.e. to understand the benefits of those solutions). If that is the case, then using human metrics for trust and verification might inhibit the creative development of gen-AI models. On the other hand, by allowing gen-AI models to evaluate and monitor themselves, we might allow the creation of an AI Frankenstein. Achieving the right balance in this tradeoff is an open question.

Current gen-AI models, as many of the AI models of the past, are essentially black box systems, meaning that they are extremely difficult to analyze, and we still don't understand how they make decisions. However, a detailed understanding of a complex system is not always necessary to evaluate it and to predict its behavior. For example, even though our understanding of the human brain is quite limited, we are still able to evaluate it for healthy functionality and detect disorders by using various tests [2]. Can we possibly use a similar approach to evaluate a gen-AI model and determine if it is processing information 'correctly', or if it has a 'disorder', e.g. is likely to hallucinate? What would be a battery of tests to evaluate a gen-AI model?

Objective: The objective of this MURI is to advance our understanding of large-scale generative AI models and develop a new theory for their analysis. Specifically, the aim is to develop principled, rigorous methods and tools to evaluate any pre-trained gen-AI model quickly and reliably. In addition, the tools should be able to continuously monitor and assess the model to capture undesirable behaviors. The evaluation of gen-AI calls for testing procedures and metrics. These can often be fluid, since they relate to cognitive and social parameters. Nevertheless, the properties of interest can be tentatively defined as follows: reliability (accuracy of answers, e.g., compared to ground-truth if available), robustness (consistency of answers, e.g., independent of variations in the prompting), trustworthiness (answers should not be misleading, which would possibly imply hidden bias or tampering), expertise (the scope of potential solutions), and even helpfulness (which may include the ability to provide steps towards the solution, even if not able to obtain at first).

Research Concentration Areas: Suggested research areas may include but are not restricted to 1) Network science. Develop methods for analyzing the dynamics of gen-AI models and investigate if different patterns of state variables or processing information can be associated with undesirable behaviors such as hallucinations, and evasions. Design a battery of tests for quick evaluation of different properties of the model such as reliability, robustness, trustworthiness, expertise, helpfulness, etc. 2) Monitoring. Develop methods for continuous monitoring including detection of deterioration in performance, and detection of possible tampering. 3) AI-based evaluation. What types of evaluations can be relinquished to AI systems; what should the properties of those AI systems be; and how should those AI systems be trained and monitored? 4) Human-based evaluation. Develop methods for expanding the evaluation group to many thousands of human evaluators (crowdsourcing). Can methods from social-choice help with selection of expert panels and integration of individual evaluations? 5) Human and AI teaming. How should teams of human and AI agents interact and cooperate during the evaluation process? What constraints and values should be used by humans and AI agents, how should they be selected, validated and updated?
The overall topic may call for combinations of multiple disciplines, such as network science, computer science, mathematics, cognitive science, social science, and others.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, recommend maximum of one lead PI and 5-6 co-investigators. Exceptions should be discussed with Topic Chief during the white paper phase of the solicitation.

Research Topic Chief: Pedja Neskovic, ONR 31, 703-696-4304, Predrag.Neskovic.civ@us.navy.mil;

Topic 15: (ONR) Brain-inspired Large Neural Models for Intelligent Robots

Background: There has been substantial progress in developing versatile robots, yet capabilities of current robots, in most respects, are far from those of humans, due to both intelligence and hardware shortcomings. While intelligence has many facets, the focus of this topic is developing the science base for building robots that approach certain aspects of embodied human physical intelligence, namely, robots that are robust and resilient, and able to perform spatio-temporal complex multistep tasks (e.g., manipulation and assembly) using vision and touch. We note while visual recognition of objects and their affordances has advanced significantly, shape recognition from touch and modeling contact forces remain fundamental challenges. Current approaches in AI robotics are based on training Large Neural Models LNM (Large Language Models, Large Vision Models, etc.) using huge volumes of data and enormous amounts of energy. LNMs are expected to continue playing a major role in robotics, especially if brain-inspired processes are incorporated in them, as a recent example shows an LNM with bio-inspired top-down feedback reconstructs images degraded with missing parts or noise. To develop versatile robots that can perform a variety of complex tasks, in diverse environments, research is needed along several directions. This includes grounding robots in the physical world, robots that can perform long multistep tasks that require planning and sequential reasoning in near real-time. Also, robots should be able to reason about the cause of failure of each step in a multistep task, to adapt and complete the sequence or replan on the fly. We also note that developed methods must be able to generalize and adapt to a wide variety of robotic hardware. Transformer models struggle with reasoning over long time horizons, but humans are capable of long sequential tasks.

Robots approaching human-level intelligence has been a longstanding but distant goal. Recent advances in neuroscience, and further research, could provide guidelines. Much is known about the architecture of

the brain, including microcircuits and the dynamics of information flow, but these have not been incorporated into current LNMs. Analysis of the spatio-temporal patterns of cortical activity point to new directions. Recent analytical tools reveal the latent space dynamics of brain activity, allow neural manifold construction and reveal low-dimensional attractors involved in the motor control of behavior which might inform robotic control. Although less is known about how high-level reasoning emerges and is used to interpret the sensorium, recent neuroscience work has revealed binding of cortical activity during cognitive processing by widespread synchronization with high-frequency oscillations. Recent analysis of brain processes which are analogous to transformer architectures have revealed that transformers can be implemented through traveling waves in recurrent cortical networks. Such traveling waves are observed in neocortex and support a spacetime distributed population code. Model recurrent networks that support traveling waves learn 100 times fasters and can memorize inputs 100 times longer. The neocortex forms recurrent loops with the hippocampus, which supports sequence learning, and the basal ganglia, which generates motor patterns. This points to exciting new paths to exploring neuroscience informed AI for robust sequence learning. Other issues to be addressed include representation and integration of multimodal information, exploitation of prior domain information like physics and mechanics, formulating appropriate loss functions and learning algorithms that lead to strong and robust generalization capabilities, selecting the most useful data for learning, energy efficient circuits and processing units, modeling contact forces, and more.

Objective: We have two related fundamental objectives in this topic. One is to explore ways for incorporating brain-inspired processes in Large Neural Models (LNMs) to substantially enhance their capabilities. The second is, given enhanced LNM architectures, develop the science base for building resilient robots with embodied intelligence that can perform spatially complex multistep tasks, such as manipulation, assembly, and disassembly, using vision and touch.

Research Concentration Areas: Research areas include (a) Investigate cognitive and neuroscience elements that are relevant for learning to perform spatially complex sequential tasks that can be completed in the face of failures and unforeseen situations, using the ability to reason and replan on the fly; and explore methods for incorporating the findings in LNMs. Investigate certain information processing models in the brain, such as latent dynamic analysis and manifold construction, synchronization of activity and cortical traveling waves and their possible connections with transformer networks. (b) Robots with embodied intelligence must be compute-efficient. Investigate methods for reducing LNMs by exploiting the heterogenous recurrent neural circuits seen in the brain, exploring the tradeoff between levels of reduction and performance loss. Also, explore the convergence of vision and tactile sensing for haptic representations in support of robust dexterous manipulation.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting at most 6 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with topic chiefs during the white paper phase.

Research Topic Chiefs: Behzad Kamgar-Parsi, ONR 311, 703-696-5754, behzad.kamgarparsi.civ@us.navy.mil; Thomas McKenna, ONR 341, 703-696-4503, thomas.m.mckenna4.civ@us.navy.mil; Marc Steinberg, ONR 351, 703-696-5115, marc.l.steinberg.civ@us.navy.mil.

Topic 16: (ONR) Reading between the lines: Connecting Deep Ocean Currents & Bedform Morphology

Background: The seafloor carries the signature of the near-bottom circulation through sediment deposits in distinct bedforms, like sand ribbons, contourites, comet marks, deep sand dunes and mobile sand sheets, and erosional features such as scour pits and channels. Individual features reflect both the regional geomorphology—sediment composition and geologic setting—and hydrodynamics, e.g., boundary layer resuspension and transport. The hydrodynamics and geomorphology are directly coupled to one another through bottom drag and topographic scattering, which are primary mechanisms for dissipation of the ocean's kinetic energy. Since the seafloor is the ultimate repository for particulate matter, furthering our understanding of this coupled system will inform on burial rates for submarine cables and infrastructure, carbon sequestration, and interpretation of the paleorecord.

Observational technologies are now capable of co-sampling all necessary components of the coupled system. However, we lack comprehensive records of sufficient duration and breadth to fully capture coupled dynamics, thereby limiting system understanding. For example, we do not know how particular morphological structures form and evolve under variable or ephemeral flows, nor do we know the time scales under which recoverable or permanent bedform change occur. We also do not understand how these features are *modulated by* and are *markers of* an evolving ocean state, which includes an erodible seabed, two-and three-dimensional flow instabilities, and other nonlinearities. Our understanding is especially limited outside of shallow water systems which have been the focus of past studies, partially due to ease in accessibility and investment associated with coastal development and management. Across the shelfbreak and deeper, the absence of long-term coupled oceanographic and seabed measurements has limited our ability to evaluate the role, if any, that perturbations within stable systems may have in short-term or lasting bedform modification. These limitations extend across seabed environments resulting from different sources and input mechanism (e.g., terrigenous-fluvial, gravitational failure and transport, biogenic-pelagic, glaciogenic, or volcanic-volcanoclastic) that are encountered in deeper water settings.

Objective: This MURI aims to develop our knowledge of the coupled current-sediment-bedform system to a point where characteristics of the near-bottom circulation (e.g., current magnitude, direction, and variability) can be directly inferred from seafloor imaging. This project will support a tightly integrated multidisciplinary team to undertake comprehensive field data collection and model all elements of the coupled system. Measurements and modeling should 1) directly integrate with each other and 2) resolve bedform evolution, sediment properties and fluxes, and near-bottom circulation. Field measurements should be of sufficient duration to link variability in circulation with bedform evolution and to support well parameterized coupled benthic boundary layer-seabed modeling. We encourage proposals that focus on multiple types of morphological features found offshore of the shelfbreak.

Research concentration areas: Research teams must incorporate the expertise needed for observing and modeling the coupled current-sediment-bedform system—resolving bedform structures up through flow within the outer oceanic boundary layer. Research concentration areas could include, but are not limited to, fluid dynamics, ocean engineering, geophysics and seabed geomorphology, biogeochemistry, acoustical oceanography, benthic ecology, and numerical techniques for multimaterial systems. While funding is restricted to US institutions, international field efforts and collaborations are welcomed.

Anticipated Resources: Awards under this topic will be no more than $1.5M per year for 5 years, supporting no more than five (5) co-investigators. Exceptions warranted by specific approaches should be discussed with the topic authors during the white paper phase of the solicitation.

Research Topic Leads: Dr. Jason Chaytor (jason.d.chaytor.civ@us.navy.mil, 508-457-2351) and Dr. Emily Shroyer (703-501-7134, emily.l.shroyer.civ@us.navy.mil)

Topic 17: (ONR) Impacts of Aerosol Injection, Evolution, and Deposition on 3D Radiative Balance

Background: Global aerosol analysis and prediction (e.g., of desert dust, sea salt, agricultural smoke, volcanic ash, chem/bio/nuclear and industrial emissions) rely heavily on satellite-based two-dimensional measurements of vertically integrated aerosol optical thickness (AOT). Because many of these plumes remain stratified as they are transported, actual visibility or electro-optical attenuation is poorly forecast for optical paths that are not integrated to the top of the atmosphere or are off-nadir (e.g. horizontal visibility near the surface or slant path visibility from aircraft), and observed conditions can diverge by orders of magnitude from vertical AOT. Recent work from atmospheric profiling systems, such as the ground-based High Spectral Resolution Lidar (HSRL; Reid et al 2019), the air-based High Altitude Lidar Observatory (HALO; Carroll et al. 2022, Nowottnick et al. 2024), as well as airborne and satellite-based wind profilers (Bedka et al. 2021), can resolve structures at a high fidelity previously unconstrained by passive sensing. Further, improvements in numerical modeling physics and resolution are now facilitating the ability to resolve layers that have previously been aliased or inferred via parameterizations. These stratifications frequently covary with other atmospheric thermodynamic layering (e.g., water vapor, clouds) and wind shear, allowing new insight into inferring correlated properties and constraining physics evolution. The impact of 3D radiative effects can no longer be neglected.
A lack of vertical structure constraints makes analysis and forecast of transport and physics difficult, reduces the accuracy of radiometric corrections for land, ice, and ocean property retrievals resulting in noise and bias, and reduces the accuracy of regional aerosol analysis for air quality and other civil applications. These errors may be remedied with a better understanding of the aerosol source and transport dynamics, microphysics, and vertical properties. Further, rigorous modeling of vertical resolution and physics sensitivity can enable the next generation of numerical prediction to incorporate 3D effects and their downstream evolution. Through focused field events and targeted in-situ/remote sensing collections along with global through large eddy simulation modeling and new algorithmic development of lidar and passive profilers, progress can be made toward better aerosol injection altitude analysis, aerosol lifecycle including advection, transformation and/or deposition character, and surface/ocean retrieval correction.

Objective: The basic research goal of this topic is to improve our understanding and numerical representation of the environmental mechanisms that modulate vertical stratification/layering, transport, and deposition of source aerosols from transient and episodic sources. Via a combination of tailored field research on aerosol structure, dynamics, and profiling remote sensing as well as improved modeling, numerics, and simulation, a better understanding is expected of the three-dimensional aerosol character and impacts on optical and infrared spectra.

Research Concentration Area: Proposed efforts are expected to apply inter-disciplinary methodologies across in-situ observing, remote sensing (via surface, air, and space-based platforms), numerical modeling, and theoretical formulation to better understand the effect of improved vertical aerosol placement on physics processes, radiative balance, and predictability. Expertise is suggested to include, but is not limited to, the following interdisciplinary areas: 1. Atmospheric Composition; 2. Radiative Transfer, including hyperspectral; 3. Meteorological and Climate Dynamics and Physics; 4. Instrumentation Engineering and Remote Sensing; 5. Applied Mathematics, Numerics, and Machine

Learning; 6. Predictability. It is anticipated that research will combine multiple public datasets and computer modeling systems with novel field efforts.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Josh Cossuth, ONR, 703-696-0703, joshua.h.cossuth.civ@us.navy.mil; Dr. Daniel Eleuterio, ONR, 703-696-4303, daniel.p.eleuterio.civ@us.navy.mil

Topic 18: (ONR) Interfacial Thermal Energy Transduction

Background: A complete understanding of energy transduction, thermal dissipation, and carrier interactions is critical for designing a wide array of material composites and devices. At interfaces and surfaces in nanomaterials, these intertwined mechanisms are the foundation of modern electronic and optoelectronic technologies. The interaction and transport among carriers across the interface between two materials give rise to increased energy density, which can result in deleterious temperature rise and associated thermal boundary resistance (TBR). Recent work suggests that ultrafast energy transduction mechanisms when different thermal carriers couple across interfaces drive the TBR. For example, deleterious thermal resistances in high-power, wide bandgap devices can be rooted in the electron-phonon interactions at interfaces. In contrast, the efficiency of photon-electron-phonon thermal transport in semiconductors limit the extreme powers required in directed energy technologies. In these systems, interactions near the interface can lead to extreme situations inducing varying degrees of nonequilibrium populations among the carriers. In such cases, the picture of near-equilibrium thermal diffusion from single types of isolated thermal carriers often fails, and the coupled thermal processes among various energy carriers in varying degrees of nonequilibrium must be considered to properly account for the energy densities that dictate transport.

The challenge in correctly understanding thermal diffusion and energy conversion across interfaces in this nonequilibrium regime lies in both the predictive computational approaches and experimental metrologies that are typically employed. Molecular dynamics (MD) simulations provide some understanding of phonon transport across interfaces but combining this predictive pathway with highly energetic and nonequilibrium distributions of electrons or photons to properly model field-excited electron-phonon-interface interactions is far beyond the current capabilities. Similarly, first-principles calculations of coupled electron and phonon transport are typically limited to periodic systems with limited number of atoms, since accurately predicting the dynamics of nonequilibrium energy carriers near and at material interfaces are computationally infeasible with current approaches based on density functional theory (DFT) calculations. Recently, thermal transport measurements across interfaces have made great strides in achieving true nanoscale spatial resolution around interfaces, but to mimic the processes in high-power nanodevices, extreme perturbation to specific electron and phonon energies near interfaces need to be controlled during measurements. Coupling these measurements to additional electric fields or photonic perturbations that induce additional degrees of nonequilibrium distributions or coupled transport is also in its infancy.

Objective: The objective of this MURI topic is improved understanding of interfacial energy carrier interactions leading to new mechanisms for enhancing thermal transport at the interfaces of dissimilar materials through coupled carriers. A multidisciplinary research team will incorporate expertise in

physics, materials science, electrical engineering and mechanical engineering to design, synthesize, characterize, and understand these materials. The impact of this approach will be the development of new high-power devices with reduced junction temperatures for RF, power, and optoelectronic applications.

Research Concentration Areas: Suggested research areas include, but are not limited to: (1) Theoretical studies of interfacial transduction mechanisms including *ab-initio* quantum dynamics simulations; (2) Novel techniques to measure nanoscale thermal transport under non-equilibrium conditions; (3) Modification of nanoscale interactions through surface chemistry, pressure, and phase changes; (4) Concepts to exploit coupled interactions in thermally-limited electronic and optoelectronic devices.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than six funded faculty researchers. Exception warranted by specific proposal approaches should be discussed with the topic chiefs during the white paper phase of the solicitation.

Research Topic Chiefs: Mark Spector, ONR Code 331, mark.spector.civ@us.navy.mil
Chakrapani Varanasi, ONR Code 332, chakrapani.v.varanasi.civ@us.navy.mil

Topic 19: (ONR) Inherent stability in hybrid metal halide perovskite semiconductors through understanding of *in situ* electrochemistry

Background: Hybrid metal halide perovskite semiconductors have seen a rapid rise in performance in solar power conversion efficiency, going from 4% to 26% in just over a decade and they now rival single junction silicon cells. Early advances arose from lessons in fabricating thin, pinhole free films with tunable polycrystallinity. Significantly improved stability and band gap tuning emerged out of extensive compositional research on the $\mathbf{ABX_3}$ perovskite unit cell with mixed A-site cations that improved stability and mixed X-site halides that allowed bandgap tuning. The current state-of-the-art is silicon-like performance from materials that can be solution processed and annealed at low temperatures (e.g. 150 °C) as opposed to silicon, which requires single crystal growth at over 1400 °C. They have high optical absorption, low exciton binding energies near kT at room temperature, inherently low defect densities, shallow traps, and long carrier diffusion lengths. Along with solar cell applications, halide perovskites are promising for applications in radiation detectors, LEDs, lasers, and transistors.

The hybrid metal halide perovskite lattice has mixed ionic and covalent character. The semiconducting properties arise from the covalent character of the bonds in the cubic array of point-attached metal halide octahedra. A-site cations assemble the octahedra and can distort the cubic array and alter properties. Large A-site cations can be used to create 2D lattices. This can be useful for quantum confinement and as a means to limit diffusion of oxygen and water through the device as well as that of ions and charge. The design space for tailored semiconductor properties is large, but the easily formed mixed ionic and covalent lattices tend to show hysteresis in electronic performance related to facile movement of ions. Neutral halide ion diffusion has been seen which implies halide anion oxidation and mixed ion and electron conducting (MIEC) behavior, but the implications of MIEC behavior in perovskites has not been explored. Practical application may result in reverse electrical bias and reverse current, greatly increasing opportunities for undesired electrochemistry. The electrochemical nature of these solid-state semiconductors is not understood, and this understanding is needed for the long-term application of these materials and mitigation of associated performance and stability issues. Of particular interest is the nature

of the electrochemistry while under operation (forward and reverse bias) and the ability to differentiate between surface (charge injection) and interior electrochemical reactions.

Objective: The objective of this research is improving the understanding of electrochemical events on and within hybrid metal halide perovskites under realistic conditions with the expectation that this may lead to strategies for improved performance and stability. Specifically, study towards an enhanced fundamental understanding of: (1) the MIEC behavior of these materials and its relationship to their chemical and electrochemical stability under operating conditions; (2) how self-assembly, morphology, and grain boundary passivation can affect these processes; (3) how lattice and device structures/layers can improve stability and possibly provide self-healing.

Research Areas: Research teams need to have the ability to make and characterize high performance hybrid metal halide perovskite devices and use/develop novel methods to explore the roles of electronic and electrochemical processes under operating conditions and how they impact performance and stability. The proposed research should be multidisciplinary spanning synthesis, chemical, morphological characterization, full optical, electronic, electrochemical, and device characterization. Computation should span from *ab initio* through device modeling and simulation and should inform and be informed by experimentation. Research should include, but not be limited to, the three areas mentioned in the objectives.

Anticipated Resources: Recommend maximum of one lead PI and 4-5 co-investigators; exceptions should be discussed with the Topic Chief.

Research Topic Chiefs: Paul Armistead, ONR, james.p.armistead2.civ@us.navy.mil, 703-696-4315; Joe Parker, ONR, joseph.f.parker23.civ@us.navy.mil, 703-696-0689; Michele Anderson, ONR, michele.l.anderson24.civ@us.navy.mil, 703-696-1938

References

1. Z Xu, RA Kerner, JJ Berry, BP Rand, Iodine Electrochemistry Dictates Voltage-Induced Halide Segregation Thresholds in Mixed-Halide Perovskite Devices. *Advanced Functional Materials* 32 (33), 2203432 (2022).
2. S Wu, Y Yan, J Yin, K Jiang, F Li, Z Zeng, SW Tsang, AKY Jen, Redox mediator-stabilized wide-bandgap perovskites for monolithic perovskite-organic tandem solar cells. *Nature Energy*, 1-11 (2024).
3. Jiang, F., Shi, Y., Rana, T.R. *et al.* Improved reverse bias stability in p–i–n perovskite solar cells with optimized hole transport materials and less reactive electrodes. *Nature Energy* (2024).

Topic 20: (ONR) Visual Perception and Attention for Real-Virtual Hybrid Environments

Background: Augmented Reality (AR) displays integrate virtual items into the real world, offering novel opportunities to examine the applicability of fundamental theories of visual perception and attention. Visual perception is the process by which the brain makes sense of visual stimuli from the environment. Visual attention is the mechanism that allows for focus on specific information while ignoring other stimuli *[1]*. Within the context of cognitive psychology, there are several tasks that explore perception and attention. For example, visual search can create competition between salience in the visual field ("bottom-up processing") and prior knowledge and memory for search targets ("top-down processing")

[2]. Manipulating aspects of visual search have enabled researchers to explore phenomena such as attention distribution, inattentional blindness, and involuntary attention capture. The novel capabilities of AR *[3]* open a new area of hybrid visual processing that requires empirical research into how task-relevant virtual information overlaid on complex outdoor environments (considering factors such as motion, brightness changes, and more) influences visual perception (e.g., environmental salience), attention mechanisms (e.g., eye movements), and task performance (e.g., accuracy and reaction time). For example, theories of attention suggest that related virtual display elements such as labels should be placed near real world objects, but saliency theories indicate that this could lead to cluttered displays and decreased legibility. How to best resolve these contradictions and maximize task performance are open research questions. Addressing these questions requires: (1) an understanding of the intersection between visual perception and attention tasks (i.e., ground forces operating outdoors *[4]*) and paradigms that can be implemented using modern-day AR technologies in complex real-world environments; (2) a methodical research plan to conduct experiments that manipulate relevant variables in identified tasks using commercially available AR technologies; (3) a data analysis plan that will test hypotheses and generate results that will develop and refine theories of hybrid visual perception and attention, leading to novel information display design principles with a specific focus on AR; (4) empirically validated approaches for testing the impact of AR technologies and updating models of visual perception and attention on human task performance in outdoor ground environments.

Objective: Develop, replicate, and revise theoretical and empirical foundations of visual perception and attention using commercially available outdoor AR systems. Generate ecologically valid and theoretically grounded frameworks for how hybrid visual processing operates in real-world environments that results in novel information design principles and improves performance across a range of tasks.

Research concentration areas: The envisioned research requires multidisciplinary expertise in areas of psychology (i.e., cognitive, ecological, human factors, neuroscience), computer science (i.e., artificial intelligence/machine learning, computer vision), and engineering (i.e., optics and photonics). These fields are required to: (1) design and conduct basic research experiments within the constraints of modern-day AR technology (2) extract, analyze, and interpret data; (3) revise and validate theories and models of hybrid visual perception and attention; (4) generate novel AR display interfaces testable across various outdoor environments and tasks; and (5) experimentally manipulate AR interface designs to explore task performance improvements. Tasks and activities must represent Naval unique characteristics of complex outdoor environments, including transitions from dark to bright areas, rapid user motion, and complex primary tasks such as visual search and orienteering. For example, military personnel such as Joint Terminal Attack Controllers are required to identify, track, and communicate with fighter jets (i.e. pilots) the position of multiple moving targets in a complex, cluttered environment while maintaining full situation awareness of their immediate surroundings (i.e., making frequent head movements) during operations that can occur at all hours and across a variety of environments (urban, jungle, littoral, etc.) against threats that are looking to find them. AR systems can overlay symbology on real-world targets and other objects of interest, sharing information such as position of aircraft, ground personnel or sensors, and assist these types of military personnel by rapidly translating positional information into operationally relevant visuals – e.g. target, friendly, etc. However, these systems must balance the addition of this augmented information with effects of clutter on the environment (both air and ground) and need for continuous head scanning to assess threats or targets in hostile environments. Competitive responses to this topic call are expected to focus on the technical domains listed above with the psychological sciences as the main driver, applying scientific rigor to complex, real-world visual environments. Another important consideration is that AR technology is currently limited by field of view, brightness, refresh rate, etc. Given these constraints, a critical starting point of this research will be defining which visual

perception and attention tasks lend themselves to examination by currently available AR technologies. For example, visual search tasks that include objects placed in the far periphery are likely unimplementable in current-day or near-future AR systems. This topic does NOT seek to engineer new AR hardware or capabilities. However, experts in optics and other relevant disciplines noted above are expected to serve as team members to ensure these technologies are maximally used.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years (one lead PI and 4-5 co-investigators); exceptions should be discussed with Topic Chief during the white paper phase.

Research Topic Chief: Dr. Peter Squire, ONR 34, 202-306-1335, peter.n.squire.civ@us.navy.mil

Participants: Dr. Tom McKenna, ONR 34; Ms. Natalie Steinhauser, ONR 34; Dr. Behzad Kamgarparsi, ONR 3l; Dr. Sangeet Khemlani, NRL; Dr. Mark Livingston, NRL; Dr. Jessie Y. C. Chen, ARL; Dr. Chou Hung, ARL; Dr. Frederick Gregory, ARO; Dr. Jason H. Wong, NIWC Pacific 53622; Dr. Joeanna Arthur, DARPA; Dr. Marc Winterbottom, AFRL

References

[1] Luck, S. J., & Ford, M. A. (1998). On the role of selective attention in visual perception. *Proceedings of the National Academy of Sciences*, *95*(3), 825-830.
[2] Wolfe, J. M. (2021). Guided Search 6.0: An updated model of visual search. *Psychonomic bulletin & review*, *28*(4), 1060-1092.
[3] Schmalstieg, D., & Hollerer, T. (2016). *Augmented reality: principles and practice*. Addison-Wesley Professional.
[4] South, T. (2023, December 29). *Army's mixed reality device nears fielding with final testing in 2024*. Army Times. https://www.armytimes.com/news/your-army/2023/12/29/armys-mixed-reality-device-nears-fielding-with-final-testing-in-2024/.
[5] I. Kotseruba and J. K. Tsotsos, (2024). Data Limitations for Modeling Top-Down Effects on Drivers' Attention. *2024 IEEE Intelligent Vehicles Symposium*, Republic of Korea, 1345-1352.

Topic 21: (ONR) Continuous Improvement and Assessment to Achieve Autonomous Skilled Performance

Background: Skill learning in humans typically starts with learning declarative knowledge about the specific steps in a procedure (e.g., knowledge about what or why that is accessible in long-term memory and is consciously observable). However, with practice in valid environments, the steps become automated. They become decision and action sequences that are automatically triggered by the task context and patterns of environmental cues with little or no conscious thought. Eventually, at high levels of skill, it becomes impossible for a person to reliably reconstruct many of the conditional sequences intervening between external cues and their actions. Consequently, many attempts to explicitly duplicate human skilled performance in autonomous and robotic systems have not been successful over the past half century. Further, while the last five years have seen significant examples of Artificial Intelligence becoming competitive with people at intellectual tasks, there has been much more limited progress at physical tasks requiring skilled performance. This lack of progress is particularly notable towards acquiring militarily relevant skills needed to operate robustly in complex, unstructured, dynamic, harsh environments with uncertainty, limited resources, and a need to make fast decisions with limited

information. For example, not only do autonomous systems lack the ability to autonomously construct or repair military infrastructure like a dock or an aircraft hangar at an austere forward operating location, but even building complex models on a tabletop in ideal conditions using toy construction sets designed for children ages seven to twelve remains remarkably challenging despite considerable recent advances in robotic manipulation.

The intersection between machine learning, cognitive neuroscience, virtual/augmented reality testbeds, high resolution human/environment sensing, and ecological psychology/dynamics may substantially increase our ability to gain a deep understanding of the information and strategies used by humans and to develop new engineering frameworks and mathematical models for autonomous systems. Recent progress in robotic learning from a modest number of demonstrations, trial examples or curriculum has been impressive on simple, short duration household and office tasks. Cognitive science, neuroscience, psychology, and human factors offer computational and theoretical frameworks and methods to identify conscious/unconscious cues and decision points during both the skill development process and after skills are acquired. Ecological psychology can provide alternative frameworks and methods for studying human perception-action relationships relating to how humans perform competently across different real-world environments. While prior efforts struggled to mechanize computational models in ways that are machine actionable, advances in foundation models may enable robust components such as for pattern matching, mental models, world simulation, and skill improvement. Similarly, neuroscience has made progress identifying when people detect a surprising audio/visual cue, and this could be combined with high resolution sensing/characterizing of the environment and machine learning methods to identify the most likely cues used in skilled performance. These results could be further refined and tested in virtual/augmented reality experiments with manipulated cues and in robotic systems in parallel virtual or real environments.

Objective: To gain a deep understanding of the information and strategies used by skilled adults, and to develop new engineering frameworks and mathematical models to utilize this understanding within autonomous systems including understanding how valid learning and instruction environments for achieving skilled adults and machines differ. This includes understanding of how to ground the skills to perception/action across multiples contexts in dynamic environments with uncertain information and time-critical requirements. The modeling scope emphasis is not on the individual neural level of circuitry, but on models involving higher levels of abstraction. Task emphasis should be on physical tasks that could be done by both machines and people, and that people might learn through a combination of reading/classroom instruction and moderate amounts of the right kind of practice and experience. Examples of motivating problems include but are not limited to (1) construction, assembly, repair, and disassembly of structures involving significant numbers of part types, extending to cases in which standard instructions are insufficient because a part/tool might be missing/imperfect or the environmental characteristics might lead to a need for modification, (2) aggressive vehicle maneuvering across different environments of increasing challenge and risk, (3) loading, configuring and unloading heterogeneous cargo on and off vehicles, extending to cases of irregularly and awkwardly shaped objects and ones requiring special handling.

Research Areas: Multidisciplinary across Artificial Intelligence/Autonomy/Robotics, Control Theory, Virtual/Augmented Reality, Cognitive Neuroscience, Ecological Psychology, and Training. Research areas include (1) enhancing substantially the accessibility of cognitive and perceptual operations in adults to better understand the skill acquisition process to professional quality levels, devising and validating experimental methods that can reliably identify the cognitive elements—critical decisions, decision points, procedures, cues, environmental conditions —that underlie skilled performance, (2) developing

computational models of the relevant cognitive processes and skill acquisition that are appropriate for autonomous and robotics systems frameworks, and (3) new principles and methodologies for grounding these models in autonomous perception and action to enable skilled performance in dynamic, unstructured, uncertain domains.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of $1.5M per year for 5 years, supporting no more than 8 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase.

Research Topic Chief: Marc Steinberg, ONR, marc.l.steinberg.civ@us.navy.mil, (703) 696-5115, Michael Qin, (703) 696–2833, Brian Holm-Hansen, brian.holm-hansen.civ@us.navy.mil, (703) 588-1047

Topic 22: (ONR) Gas/Material Interactions for Ultra-high-temperature Materials in Hypersonic Flows

Background: Planetary entry and hypersonic flight generate extreme thermal, structural, and chemical environments with gas temperatures in the shock layer exceeding 10,000 Kelvin, leading to oxygen dissociation in the vehicle's boundary layer. The prevalence of highly reactive atomic oxygen in the boundary layer significantly enhances the surface oxidation and oxygen diffusion within the material of the vehicle's thermal protection system (TPS). Gas/material interactions (GMI) under such extreme conditions involve complex and poorly understood processes both at the material surface (e.g., adsorption, desorption, and catalytic recombination) and in the subsurface (e.g., species diffusion and reaction, and thermal conduction).

In the last few decades, progress in the discovery and development of ultra-high temperature ceramics (UHTCs), a new class of materials capable of withstanding extreme environments, has been hampered by a lack of understanding of atomic-level interactions with gases in the boundary layer and the material response. This topic aims to understand the material response under realistic hypersonic flight conditions, focusing on minimizing ablation rather than preventing oxidation, to enable shape-stable TPS. Hypersonic flight presents a unique scenario where short-term exposure to extreme conditions introduces new challenges and opportunities for material response. At the temperatures and oxidation conditions anticipated in hypersonic flight, oxidation is thermodynamically favored and likely unavoidable. Understanding the formation mechanisms of protective scales or layers during gas/material interactions (GMI) could enable the design of revolutionary self-healing ultra-high temperature ceramic composites for TPS, with an in-situ capability to slow down reaction pathways, especially after the protective scale has been damaged by impact. This topic will emphasize the fundamental understanding required to meet future hypersonic vehicle requirements by fostering close collaboration between materials scientists and aerothermodynamicists. This synergy aims to drive the development of a comprehensive theoretical framework, enabling the discovery of materials that meet these stringent conditions.

Over the last 15 years, the use of ab initio quantum chemistry methods and molecular beam experiments have enabled improved finite-rate air chemistry and air-carbon ablation models for ordered carbon surfaces. This progress can be leveraged and applied to the newer class of UHTC materials through new multidisciplinary research to understand GMI of the oxidation and growth of oxide layers on ultra-high temperature materials subjected to hypersonic flows due to their complex oxidation and material response behavior. Moreover, this MURI topic encourages leveraging recent scientific advances in multiscale computational methods (e.g., accelerated Molecular Dynamics, Density Functional Theory, and Kinetic

Monte Carlo) and Bayesian-based data assimilation to integrate experiments and computations. Other notable advancements include machine learning-driven entropy-based descriptors for identifying optimal composition and in-situ diagnostics (e.g., Laser-Induced Breakdown Spectroscopy, X-ray Photoelectron Spectroscopy, Synchrotron-based X-ray Diffraction, Laser-Induced Fluorescence (LIF), and Coherent Anti-Stokes Raman Spectroscopy (CARS)) to characterize fundamental processes in the condensed (solid and liquid) and gas phases in real time. The new methodologies and insights developed through this research will establish a new paradigm with potential applicability to space exploration and satellite technology, driving future advancements in durable TPS and spacecraft materials.

Objective: The objective of this MURI is to develop a scientific framework to understand, model, and predict GMI of UHTCs in hypersonic flows, incorporating multiscale approaches to rigorously model processes from atomic-level surface reactions to mesoscale structures and phase equilibria. Relevant processes include the formation of new gas, liquid, glassy, and crystalline phases driving the adherence of the oxide scale. This framework must encompass rigorous physics-based methodologies to connect findings from high-enthalpy experiments to hypersonic flight conditions and translate results from simplified coupon experiments to the complex geometries, curvatures, features, and interfaces present in full-scale TPS. Progress requires the understanding of relevant fundamental processes such as oxide layer growth, volatilization, the spatiotemporal evolution of its morphology, and its effect on the boundary layer; subsurface species diffusion and reactions; hysteresis effects due to varying flow conditions; and surface energy accommodation – all insights that could enable revolutionary advancements in TPS materials.

Concentration Areas: Suggested concentration areas include but are not limited to: (1) Computational chemistry to predict expected volatiles and reaction barriers for materials of interest; (2) Materials science to understand and model the effect of materials composition, microstructure, imperfections, impurities, and defects; (3) Experiments with advanced diagnostics for in-situ characterization of the gas-phase, surface, and subsurface processes; and (4) Development of experimentally validated numerical models to predict GMI in hypersonic flows over all relevant spatiotemporal scales including the evolution of oxide layers, in-depth changes, and surface roughness, to enable material discovery.

Anticipated Resources: It is anticipated that awards under this topic will be at an average of $1.5M per year for 5 years supporting a multi-disciplinary team of 5-7 faculty researchers.

Research Topic Chiefs: Dr. Eric Marineau, 703-696-4771, eric.c.marineau.civ@us.navy.mil; 301-227-3949; Dr. Chakrapani Varanasi, ONR 332, 919-549-4325 chakrapani.v.varanasi.civ@us.navy.mil; Dr. Michael R. Berman, AFOSR, 703-696-7781, michael.berman@us.af.mil;