

ONR FOA Announcement Number: ONRFOA 14-012
FUNDING OPPORTUNITY ANNOUNCEMENT (FOA)

Fiscal Year (FY) 2015 Department of Defense Multidisciplinary Research Program of the University
Research Initiative

Amendment 0001

5 Dec 2014

The funding announcement is revised to extend the full proposal due date for MURI Topic 14, *Visual Commonsense for Scene Understanding*, from 23 Feb 2015 to 23 Mar 2015. All other topics are due 23 Feb 2015.

Changes to the due date for Topic 14 are found in **bold** in the following sections of the FoA:

Section I, Paragraph 5. Response Date

Section IV, Application and Submission Information, Paragraph 3. Significant Dates and Times

End Amendment 0001

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INTRODUCTION:

This publication constitutes a Funding Opportunity Announcement (FOA) as contemplated in Department of Defense Grant and Agreement Regulation (DODGARS) 22.315(a). A formal Request for Proposals (RFP), solicitation, and/or additional information regarding this announcement will not be issued.

The Office of Naval Research (ONR) will not issue paper copies of this announcement. The ONR and Department of Defense (DoD) agencies involved in this program reserve the right to select for award all, some or none of the proposals submitted in response to this announcement. The ONR and other participating DoD agencies provide no funding for direct reimbursement of proposal development costs. Technical and cost proposals (or any other material) submitted in response to this FOA will not be returned. It is the policy of ONR and the other participating DoD Services to treat all proposals as sensitive competitive information and to disclose their contents only for the purposes of evaluation.

The DoD Multidisciplinary University Research Initiative (MURI), one element of the University Research Initiative (URI), is sponsored by the DoD research offices: 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").

Awards will take the form of grants. Therefore, proposals submitted as a result of this announcement will fall under the purview of the Department of Defense Grant and Agreement Regulations (DoDGARs).

NOTICE: Significant changes in funding and researcher team sizes have been made in this FOA. Please review carefully, in order to ensure that MURI projects under each topic are appropriately funded and that the size of research teams allows adequate funding for each faculty member to effectively contribute to exploring the scientific opportunities in the topic area, EACH MURI topic description will identify the topic chief's estimation of the anticipated funding available and the appropriate team size. Any requested exceptions should be discussed with the topic chief during the white paper phase of the solicitation. The adequacy of support for each researcher will be an evaluation criterion in the source selection process.

In addition to the changes noted above, the following changes are noted:

- Opportunities to attract UK funding for proposals with UK collaborators in selected topics are described in section III 2.
- A requirement that the project summary / abstract required in the submission of the proposal must be publically releasable is noted in section IV 2b.
- The notice that advisors external to the 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 V 2.

Potential offerors may obtain information on ONR programs and opportunities by checking the ONR website at: <http://www.onr.navy.mil/en/Contracts-Grants.aspx>

I. GENERAL INFORMATION

1. Agency Name

Office of Naval Research, Code 03R
One Liberty Center
875 North Randolph Street
Arlington, VA 22203-1995

2. Research Opportunity Title

Multidisciplinary University Research Initiative (MURI)

3. Program Name

Fiscal Year (FY) 2015 Department of Defense Multidisciplinary Research Program of the University Research Initiative

4. Research Opportunity Number

ONRFOA 14-012

5. Response Date

White Papers: 24 Nov 2014 (Monday)

Full Proposals: 23 Feb 2015 (Monday) – All topics with exception of Topic 14

US/UK Topic 14. *Visual Commonsense for Scene Understanding* full proposal: 23 Mar 2015 (Monday)

6. Research Opportunity 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 by the DoD, "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). DoD's basic research program invests broadly in many specific fields to ensure that it has early cognizance of new scientific knowledge.

The FY 2015 MURI competition is for the topics listed below. Detailed descriptions of the topics can be found in Section VIII, entitled, "Specific MURI Topics," of this FOA. The detailed descriptions are intended to provide the offeror 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.

White papers and full proposals addressing the following topics 1 through 8 should be submitted to the Army Research Office (ARO):

1. Emulating the Principles of Impulsive Biological Force Generation
2. Exploiting nitrogen vacancy diamonds for manipulation of biological transduction
3. Noncommutativity in Interdependent Multimodal Data Analysis
4. Multi-scale Response for Adaptive Chemical and Material Systems
5. New Regimes in Quantum Optics
6. Fractional Order Methods for Sharp Interface Flows
7. 2-Dimensional Organic Polymers
8. Network Science of Teams

White papers and full proposals addressing the following topics 9 through 13 should be submitted to the Air Force Office of Scientific Research (AFOSR):

9. Exploiting Biological Electromechanics: Using Electromagnetic Energy to Control Biological Systems
10. Large Scale Nano-Architecture Formation
11. Membrane-Based Electronics: Foldable & Adaptable Integrated Circuits
12. Semantics and Structures for Higher-level Quantum Programming Languages
13. Strong Field Laser Matter Interactions at Mid-Infrared Wavelength

White papers and full proposals addressing the following topics 14 through 19 should be submitted to The Office of Naval Research (ONR):

14. Visual Commonsense for Scene Understanding
15. Characterization and Prediction of Remotely Sensed Mesoscale Aerosols in Coastal and Maritime Atmospheric Boundary Layers for Electro-optical Propagation
16. Role of the Host Microbiome on Behavior/Resilience in Response to Stressors
17. Metalloid Cluster Networks
18. Computational and Experimental Methods towards Understanding the Chemistry and Physics of

Materials over 2000°C

19. Quantum Optomechanics

Proposals from a team of university investigators are warranted when the necessary expertise in addressing the multiple facets of the topics may reside in different universities, or in different departments in the same university. 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.

For topics 5, 13, and 14, proposals are invited that include participation from UK academic institutions (see Section III 2), although this is not a requirement. In the case of proposals with UK participation, there still should be a single US primary institution and one PI submitting the overall proposal. However, funding for the UK participation will be allocated separately by the UK government.

7. Point(s) of Contact

One or more Research Topic Chiefs are identified for each specific MURI Topic. Questions of a technical nature shall be directed to one of the Research Topic Chiefs identified in Section VIII entitled “Specific MURI Topics” of this FOA.

Questions of a *policy* nature for all three (3) services shall be directed to ONR as specified below:

ONR MURI Program Point of Contact:

Dr. Ellen Livingston
MURI Program Manager
Office of Naval Research, Code 03R
E-mail Address: ellen.s.livingston@navy.mil

Mailing address:
Office of Naval Research One Liberty Center
875 North Randolph Street, Suite 1409
Arlington, VA 22203-1995

Questions of a *business nature* for all three (3) services shall be directed to ONR as specified below:

Primary:
Ms. Mary Helen Dent Adams
Code ONR 0254
Office of Naval Research
875 North Randolph Street
Arlington, VA 22203-1995
E-Mail: mary.dent@navy.mil

Note: Responses to questions will be coordinated with a Grants Officer.

Questions submitted after Monday, 10 Nov 2014 for white papers and Monday, 9 Feb 2015 for full proposals, may not be answered and the due date for submission of the white paper and/or full proposal will not be extended. Answers to questions submitted in response to this FOA will be addressed in the

form of an amendment and will be posted to one or more of the following webpages:

- Grants.gov Webpage – <http://www.grants.gov/>
- ONR Contracts and Grants Webpage - <http://www.onr.navy.mil/Contracts-Grants.aspx>

8. Instrument Type(s)

It is anticipated that all awards resulting from this announcement will be grants. Examples of model grants can be found on the ONR website at the following link: <http://www.onr.navy.mil/en/contracts-Grants/submit-proposal/grants-proposal/model-grant.aspx>

9. Catalog of Federal Domestic Assistance (CFDA) Numbers

12.300 ONR
12.800 AFOSR
12.431 ARO

10. Catalog of Federal Domestic Assistance (CFDA) Titles

Basic and Applied Scientific Research, (ONR)
Air Force Defense Research Sciences Program, (AFOSR)
Basic Scientific Research, (ARO)

Work funded under this FOA must be basic research and falls under the guidance of the Under Secretary of Defense (Acquisition, Technology, and Logistics) Memorandum of 24 MAY 2010.

II. AWARD INFORMATION

It is anticipated the awards will be made in the form of grants to universities. The awards will be made at funding levels commensurate with the proposed research and in response to agency missions. Each individual award will be for a three year base period with one two-year option period to bring the total maximum term of the award to five years. The base and option periods, if exercised, will be incrementally funded.

The Total amount of funding for five years available for grants resulting from this MURI FOA is estimated to be approximately \$145 million dollars pending out-year appropriations. MURI awards are \$1M- \$2.5M per year, with the actual amount contingent on availability of funds, the specific topic, and the scope of the proposed work. Typical annual funding is in the \$1.25M to \$1.5M range, while funding for collaborative US / UK topics should be discussed with the topic chief. The amount of the award and the number of supported researchers should not exceed the limit specified for the individual topics in Section VIII. It is strongly recommended that potential proposers communicate with the Research Topic Chiefs 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.

III. ELIGIBILITY INFORMATION

1. General Eligibility:

This MURI competition is open only to and full proposals are to be submitted only by U.S.

institutions of higher education (universities) including DoD institutions of higher education, with degree-granting programs in science and/or engineering. To the extent that it is a part of a U.S. institution of higher education and is not designated as a Federally Funded Research and Development Centers (FFRDC), a University Affiliated Research Center (UARC) or other University Affiliated Laboratory (UAL) is eligible to submit a proposal to this MURI competition and receive MURI funds. However, the eligibility of a UAL (other than an FFRDC) to submit a URI proposal does not exempt the proposal from any evaluation factor contained in this FOA. Ineligible organizations (e.g., industry, DoD laboratories, FFRDCs, and foreign universities) may collaborate on the research but may not receive MURI funds, directly or via subaward.

When a modest amount of additional funding for an ineligible organization is necessary to make the proposed collaboration possible, such funds may be requested via a separate proposal from that organization. This supplemental proposal should be attached to the primary MURI proposal and will be evaluated separately by the responsible Research Topic Chief. If approved, the supplemental proposal will be funded by the responsible agency using non-MURI funds. Since it is not certain that non-MURI funding would be available for ineligible organizations, Principal Investigators are encouraged to restrict funding requests to eligible organizations when practical.

2. Eligibility for US/UK collaborative proposals:

Topics 5, 13, and 14 have been designated as topics with the potential for special US/UK collaboration. For these topics, proposals are invited to include UK academic institutions. A separate agreement between the US and UK governments specifies that additional funding support for the UK collaborators can be provided by the UK government. The amount of support appropriate for UK collaborating teams should be discussed with the topic chief for topics identified for US/UK collaboration. In these topics proposals may be submitted with or without UK collaborators. There is no specific consideration or advantage given to proposals with UK collaborators, rather any proposal will be evaluated using the criteria described in subsection VI applied to the proposal in its entirety. PI's submitting proposals with UK collaborators are strongly encouraged to discuss their planned proposal and funding requested, with the appropriate topic chief during the white paper stage.

The Federal Funding Accountability and Transparency Act of 2006 (Public Law 109-282), as amended by Section 6202 of Public Law 110-252, requires that all agencies establish requirements for recipients reporting information on subawards and executive total compensation as codified in 2 CFR 170.110. Any U.S. Institutions of Higher Education that applies for financial assistance (either grants, cooperative agreements or other transaction agreements) as either a prime or sub-recipient under this FOA 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 170.220. An entity is exempt from this requirement UNLESS in the preceding fiscal year it received: a) 80 percent or more of its annual gross revenue in Federal contracts (and subcontracts), loans, grants (and subgrants), and cooperative agreements; b) \$25 million or more in annual gross revenue from Federal contracts (and subcontracts), loans, grants (and subgrants), and cooperative agreements; and c) the public does not have access to information about the compensation of the senior executives through periodic reports filed under section 13(a) or 15(d) of the Securities Exchange Act of 1934 or section 6104 of the Internal Revenue Code of 1986.

IV. APPLICATION AND SUBMISSION INFORMATION

1. Application and Submission Process

Regardless of whether or not a non-MURI funded collaboration is included in the proposal, and in particular if a UK academic collaboration is included, the same submission process for white papers and full proposals will be followed.

The proposal submission process is in two stages. Prospective awardees are encouraged to submit white papers to minimize the labor and cost associated with the production of detailed full 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 full proposals. The Research Topic Chief may also on occasion, provide feedback encouraging reteaming to strengthen a proposal.

Due Date: The due date and time for receipt of white papers is no later than 4:00 P.M. (Eastern Time) on Monday, 24 Nov 2014.

Submission of White Papers:

White papers may be submitted via e-mail directly to a Research Topic Chief, via the United States Postal Service (USPS), or via a commercial carrier to the agency specified for the topic. For hard copy submissions, use the addresses provided in Section IV entitled "Application and Submission Information" paragraph number 5 entitled "Address for the Submission of Hard Copy White Papers." White papers should be stapled in the upper left hand corner; plastic covers or binders should not be used. Separate attachments, such as individual brochures or reprints, will not be accepted. Do not email 1) .ZIP files; and 2) password protected files.

Evaluation/Notification: Initial evaluations of the white papers will be issued on or about Monday, 8 Dec 2014.

Submission of Full Proposal:

Any offeror may still submit a full proposal even if its white paper was not identified as being of "particular value" to the Government or if no white paper was submitted. However, the initial evaluation of the white papers should give prospective awardee some indication of whether a later full proposal would likely result in an award.

NOTE: Full Proposals must be submitted electronically through grants.gov.

2. Content and Format of White Papers and Full Proposals

The white papers and full proposals submitted under this FOA are expected to address unclassified basic research. White papers and full proposal submissions will be protected from unauthorized disclosure in accordance with applicable laws and DoD regulations. Offerors are expected to appropriately mark each page of their submission that contains proprietary information. Grants awarded under this announcement shall be unclassified.

Important Note: Titles given to the White Papers/Full Proposals should be descriptive of the basic research they cover and not be merely a copy of the topic title.

a. White Paper Submission: Contents and Format of Applications

Each topic in this announcement has one or more Research Topic Chiefs identified from one of the participating agencies; ONR, AFOSR, or ARO. You should submit your white paper to one of the Research Topic Chiefs at the agency to which you are applying.

White paper format should be as follows:

- Paper Size - 8.5 x 11 inch paper
- Margins - 1 inch
- Spacing – single spaced
- Font - Times New Roman, 12 point
- Number of Pages - no more than four (4) single-sided pages (excluding cover letter, cover, and curriculum vitae). White paper pages beyond the 4-page limit may not be evaluated or read.
- Copies – Hard Copy Submissions: one (1) original and two (2) copies.
- White Paper content should be as follows:
 - A one page cover letter (optional)
 - A cover page, labeled "PROPOSAL WHITE PAPER," that includes the FOA number, proposed title, and proposer's technical point of contact, with telephone number, facsimile number, e-mail address, topic number, and topic title
 - 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
 - Identification of any Organizational Conflict(s) of Interest (if any) - See Section VII, Paragraph 7 for more details.

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 institutional signatures.

b. Grants.gov Full Proposal Submission:

Application forms and instructions are available at Grants.gov. To access these materials, go to <http://www.grants.gov>, select "Apply for Grants", and then select "Download Application Package". Enter the CFDA for the respective agency to which you are directing the application (ONR – 12.300, AFOSR – 12.800, ARO – 12.431), as found on page four of this announcement) and the funding opportunity number, designated as “research opportunity number” on page two of this FOA. Each topic in this announcement has a Research Topic Chief identified from one of the participating agencies; ONR, AFOSR, or ARO. You should direct your application to the agency associated with the topic to which you are applying.

None of the DoD agencies participating has specified additional full proposal submission criteria. Full proposals must be submitted through grants.gov.

Content and Form of Application: –

You must complete the mandatory forms in accordance with the instructions on the forms and the additional instructions below. Files that are attached to the forms must be in Adobe Portable Document Format (PDF) unless otherwise specified in this announcement.

Form: SF 424 (R&R) - Mandatory

Complete all the required fields in accordance with the pop-up instructions on the form. To activate the instructions, turn on the “Help Mode” (icon with the pointer and question mark at the top of the form). The following information must be completed in the SF 424 located on www.grants.gov to ensure that the application is directed to the correct individual for review and to be considered for award, Offerors

must fill out block 4 of the SF 424 R&R as follows: Block 4a “Federal Identifier”: leave blank; Block 4b “Agency Routing Identifier”: enter the appropriate Research Topic Chief’s name.

Form Research & Related Other Project Information - Mandatory

To attach the technical proposal in Grants.gov, download the application package;
Click on "Research and Related Other Project Information";
Click on "Move form to Submission List";
Click on "Open Form"; and
You will see a new PDF document titled "Research & Related Other Project Information"

Project Summary/Abstract (Field 7 on the Form) - Mandatory

The project summary should be a single page that identifies the research problem, technical approaches, anticipated outcome of the research, if successful, and impact on DoD capabilities. The project summary must be appropriate for public release. The project summaries of all awarded proposals will be placed on DoD websites open to the public, regardless of restrictive markings. It should identify the Principal Investigator; the university and other universities involved in the MURI team if any; the proposal title; the agency to which the proposal is submitted; and the MURI topic number and the total funds requested from DoD for the 3-year base period, the 2-year option period and the 5-year total period. The project summary must not exceed 1 page when printed using standard 8.5” by 11” paper with 1” margins (top, bottom, left and right) with font Times New Roman 12 point. To attach a Project Summary/Abstract, click “Add Attachment.” and attach the project summary/abstract. (You will not be able to type in the box, therefore, save the file you want to attach as Project Summary or Abstract).

Project Narrative (Field 8 on the form) - Mandatory

To attach a Project Narrative in field 8 click on “Add Attachment” and attach the technical proposal. (Save the file as Volume I- Technical Proposal since you will not be able to type in the box). All applications should be in a single PDF file.

The Following Formatting Rules Apply for Field 8

- Paper size when printed - 8.5 x 11 inch paper
- Margins - 1 inch
- Spacing - single
- Font - Times New Roman, 12 point
- Number of pages - no more than twenty-five (25) single-sided pages.

The cover, table of contents, list of references, letters of support, and curriculum vitae are excluded from the page limitations. The pages of full proposals exceeding the page limit may not be included in the evaluation.

Include the Following in Field 8

The first page of your narrative must include the following information:

- Principal Investigator name
- Phone number, fax number and e-mail address
- Institution, Department, Division
- Institution address
- Other universities involved in the MURI team

- Current DoD Contractor or Grantee? If yes, provide Agency, point of contact; and phone number.
 - Proposal title
 - Institution proposal number
 - Agency to which proposal is submitted
 - Topic number and topic title
 - Table of Contents: List project narrative sections and corresponding page numbers.
 - Technical Approach: Describe in detail the basic research in science and/or engineering to be undertaken. State the objective and approach, including how data will be analyzed and interpreted. 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. Discuss the nature of expected results. Describe plans for the research training of students. Include the number of full time equivalent graduate students and undergraduates, if any, to be supported each year. Discuss the involvement of other students, if any.
 - Project Schedule, Milestones and Deliverables: A summary of the schedule of events, milestones, and a detailed description of the results and products to be delivered.
 - Management Approach: A discussion of the overall approach to the management of this effort, including brief discussions of: required facilities; relationships with any subawardees and with other organizations; availability of personnel; and planning, scheduling and control procedures.
- (a) Describe the facilities available for the accomplishment of the proposed research and related education objectives. Describe any capital equipment planned for acquisition under this program and its application to the proposed research. If possible, budget for capital equipment should be allocated to the first budget period of the grant. Include a description of any government furnished equipment/hardware/software/information, by version and/or configuration that are required for the proposed effort.
- (b) Describe in detail proposed subawards to other eligible universities or with other eligible institutions. If subawards to other universities are proposed, make clear the division of research activities, to be supported by detailed budgets for the proposed subawards.
- (c) Designate one individual as the Principal Investigator for the award, for the purpose of technical responsibility and to serve as the primary point-of-contact with an agency's Research Topic Chief. Briefly summarize the qualifications of the Principal Investigator and other key investigators who will conduct the proposed research.
- (d) List the amount of funding and describe the research activities of the Principal Investigator and co-investigators in on-going and pending research projects, whether or not acting as Principal Investigator in these other projects, the time charged to each of these projects, and their relationship to the proposed effort.
- (e) Describe plans to manage the interactions among members of the proposed research team.
- (f) Identification of Organizational Conflict of Interest (if any) – See Section VII, Paragraph 7 for more details.

(g) Identify other parties to whom the proposal has been, or will be sent, including agency contact information.

- List of References: List publications cited in above sections.
- Letters of Support: Up to three Letters of Support, describing agency interest in the topic area or expressing a commitment for support, from various DoD agencies may be included.
- Curriculum Vitae: Include curriculum vitae of the Principal Investigator and key co-investigators.

Bibliography & References Cited (Field 9 on the form)

Facilities & Other Resources (Field 10 on the form)

Equipment (Field 11 on the form)

Other Attachment (Field 12 on the form)

Attach the budget proposal at field 12. You must provide a detailed cost breakdown of all costs, by cost category and by the funding periods described below, corresponding to the proposed Technical Approach which was provided in Field 8 of the Research and Related Other Project Information Form. The Research and Related Budget form is not required.

For US/UK funded efforts: A separate agreement between the US and UK governments specify that additional funding support for the UK collaborators can be provided by the UK government. For budget proposal purposes, UK funded proposal budgets shall be separate from US funded proposal budgets.

The budget should adhere to the following guidelines:

Detailed breakdown of all costs, by cost category, by the calendar periods stated below. For budget purposes, use an award start date of 6 Jul 2015 (Monday). For the three-year base grant, the cost should be broken down to reflect funding increment periods of:

- (1) Three months,
- (2) Twelve months,
- (3) Twelve months, and
- (4) Nine months

Note that the budget for each of the calendar periods should include only those costs to be expended during that calendar period. The budget should also include an option for two additional years broken down to the following funding periods:

- (1) Three months
- (2) Twelve months, and
- (3) Nine months

Annual budget should be driven by program requirements. Elements of the budget should include:

- Direct Labor – Individual labor categories or persons, with associated labor hours and unburdened direct labor rates. Provide escalation rates for out years.
- 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 and Indirect Costs (i.e., 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, provide a copy of the memorandum/agreement. If the rates have not been approved/negotiated, provide sufficient detail to enable a determination of allowability, allocability and reasonableness of the allocation bases and how the rates are calculated. Additional information may be requested, if needed. If composite rates are used, provide the calculations used in deriving the composite rates.
- Travel – The proposed travel cost should include the following 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 principals.
- Subawards – 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). A proposal and supporting documentation must be received and reviewed before the Government can complete its cost analysis of the proposal and enter negotiations. The preferred method of receiving subcontract information is for this information to be included with the Prime's 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, the prime Offeror, and that the attached proposal is a subcontract. Fee/Profit guidance is noted below.
- Consultants – Provide a breakdown of the consultant's hours, the hourly rate proposed, 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 contractor's proposal.
- Materials & Supplies – Provide an itemized list of all proposed materials and supplies including quantities, unit prices, proposed vendors (if known), 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 would be 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, office equipment and furnishings, etc.) 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.
- Other Direct Costs – Provide an itemized list of all other proposed other direct costs such as Graduate Assistant tuition, laboratory fees, 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 subcontracts issued by the prime awardee.

Funding Breakdown

Funding breakdown corresponding to the proposed Technical Approach which was provided in Field 8 of the Research and Related Other Project Information Form must also be attached.

NOTE: Full Proposals must be submitted electronically through grants.gov.

Submission of Grant Proposals through Grants.gov

Detailed instructions entitled “Grants.Gov Electronic Application and Submission Information” on how to submit a Grant proposal through Grants.gov are under the Acquisition Department — Submitting a Proposal section of the website at <http://www.onr.navy.mil/Contracts-Grants/submit-proposal/grants-proposal/grants-gov.aspx>.

By completing Block 17 of the SF 424 R&R the Grant Applicant is providing the certification on lobbying required by 32 CFR Part 28. Refer to Section VI, ‘Award Administration Information’ entitled “Certifications” for further information.

For electronic submission of grant full proposals, there are several one-time actions that must be completed in order to submit an application through Grants.gov. These include obtaining a Dun and Bradstreet Data Universal Numbering System (DUNS) number, registering with System for Award Management (SAM), registering with the credential provider, and registering with Grants.gov. See www.grants.gov, specifically www.grants.gov/GetStarted.

Use the Grants.gov Organization Registration Checklist which can be found at:

<http://www.grants.gov/web/applicants/organization-registration.html>

This document will provide guidance through the process. Designating an E-Business Point of Contact (E-Biz POC) and obtaining a special password called ‘MPIN’ are important steps in the SAM registration process. Applicants who are not registered with SAM.gov and Grants.gov should allow at least 21 days to complete these requirements. The process should be started as soon as possible. Any questions relating to the registration process, system requirements, how an application form works, or the submittal process must be directed to Grants.gov at 1-800-518-4726 (1-606-545-5035 for foreign applicants) or support@grants.gov.

Special Notices Relative to Grant Applications to be submitted through Grants.Gov:

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.

Proposal Receipt Notices:

After a full proposal is submitted through Grants.gov, the Authorized Organization Representative (AOR) will receive a series of three e-mails. It is extremely important that the AOR watch for and save each of the e-mails. You will know that your proposal has reached ONR when the AOR receives e-mail Number 3. You will need the Submission Receipt Number (e-mail Number 1) to track a submission. The three e-mails 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 e-mail 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 DUNS 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 in e-mail form from ONR within ten days from the proposal due date, if applicable. The e-mail is sent to the authorized representative for the institution. The e-mail for proposals notes that the proposal has been received and provides the assigned tracking number.

3. Significant Dates and Times

Schedule of Events		
Event	Date	Time
Questions Regarding white papers*	10 Nov 2014 (Monday)	4:00PM Eastern Daylight Time
White Papers Due	24 Nov 2014 (Monday)	4:00 PM Eastern Daylight Time
Notification of Initial DoD Evaluations of White Papers	8 Dec 2014 (Monday)	
Questions Regarding full proposals*	9 Feb 2015 (Monday)	4:00PM Eastern Standard Time
Full Proposals Due (all topics except Topic 14)	23 Feb 2015 (Monday)	4:00 PM Eastern Standard Time
Full Proposal Due (Topic 14)	23 Mar 2015 (Monday)	4:00 PM Eastern Daylight Time
Notification of Selection for Award	5 Jun 2015 (Friday) **	
Start Date of Grant	6 Jul 2015 (Monday) **	

*Questions received after this date and time may not be answered and the due date for submission of the proposals will not be extended ** These dates are estimates as of the date of this announcement.

Note: Due to changes in security procedures since September 11, 2001, the time required for hard-copy written materials to be received at the Office of Naval Research has increased. Materials submitted through the U.S. Postal Service, for example, may take seven days or more to be received, even when sent by Express Mail. Thus, any hard-copy whitepaper should be submitted long enough before the deadline established in the solicitation so that it will not be received late and thus be ineligible for consideration.

4. Submission of Late Proposals

Any full proposal submitted and validated through Grants.gov where the time and date for submission (e-mail Number #2) is after the deadline for proposal submission in Section IV entitled, "Application and Submission Information" paragraph number 3 entitled, "Significant Dates and Times" will be late and will not be evaluated unless the Grants.gov website was not operational on the due date and was unable to receive the proposal submission. If this occurs, the time specified for the receipt of proposals through Grants.gov will be extended to the same time of the day specified in this FOA on the first workday on which the Grants.gov website is operational.

Be advised that Grants.gov applicants have been experiencing system slowness and validation issues which may impact the time required submitting proposals. After proposals are uploaded to Grants.gov, the submitter receives an email indicating the proposal has been submitted and that grants.gov will take up to two days to validate the proposal. As it is possible for Grants.gov to reject the proposal during this process, it is **STRONGLY** recommended that any soft-copy proposals be uploaded at least two days before the deadline established in the solicitation so that it will not be received late and be ineligible for award consideration.

5. Address for Submission of Hard Copy White Papers

Submission of white papers shall be sent to the addresses below.

Important Notes Regarding Submission of Hard Copy White Papers: If the Offeror is using USPS, please allow an additional five (5) business days for the package to be delivered due to USPS mail being sent to a central location for special processing before it is sent to the addresses below.

U.S. Army Research Office:

Hard copy white papers addressing topics (1) to (8) should be sent to the U.S. Army Research Office at one of the following addresses:

For delivery by USPS (ordinary First Class or Priority Mail (but not Express Mail)) use:

U.S. Army Research Office (FY15 MURI) P. O. Box 12211
Research Triangle Park, NC 27709-2211

For commercial delivery (such as Express Mail, FedEx, UPS, etc.) use:

U.S. Army Research Office (FY15 MURI)
For white papers include: ATTN: (list name of responsible Research Topic Chief)
4300 S. Miami Blvd
Durham, NC 27703-9142
919-549-4211

Air Force Office of Scientific Research:

Hard copy white papers addressing topics (9) to (13) should be sent to the Air Force Office of Scientific Research at the following address:

Air Force Office of Scientific Research
ATTN: (list name of responsible Research Topic Chief)
875 North Randolph Street
Suite 325, Room 3112
Arlington, VA 22203-1768

Office of Naval Research:

Hard copies of white papers topics (14) to (19) should be sent to the Office of Naval Research at the following address: For those topics with multiple topic chiefs, send the white paper to the first topic chief listed.

Primary:
Office of Naval Research
ATTN: (list name of responsible Research Topic Chief)
875 North Randolph Street - Suite W256A* Arlington, VA 22203-1995
Point of Contact: Paula Barden
Email: paula.barden.ctr@navy.mil
703-696-4111

Secondary:
Office of Naval Research
ATTN: (list name of responsible Research Topic Chief)
875 North Randolph Street - Suite 1409* Arlington, VA 22203-1995
Point of Contact: Dr. Ellen Livingston
Email: ellen.s.livingston@navy.mil
703-696-4668

*This is the address for hand delivery, delivery via USPS and delivery via commercial delivery services.

If a telephone number is required, please use 703-696-4111 or 703-696-4668.

V. EVALUATION INFORMATION

1. Evaluation Criteria

A. Basic Research: The MURI Program is funded by basic research (Budget Activity 1) money. White papers and full 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 requirements.” The full definitions of these terms are contained in document: DoD 7000.14-R, vol. 2B, chap. 5.

White papers will be evaluated by the responsible Research Topic Chief 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 full proposal. The assessment will focus on scientific and technical merits (criterion 1, below), potential for the research to significantly advance fundamental understanding in the topic area (criterion 2 below), and potential DoD interest (criterion 3, below), although the other criteria may also be used in making the assessment.

Full proposals responding to this FOA in each topic area will be evaluated using the following criteria. The first four evaluation factors are of equal importance:

1. Scientific and technical merits of the proposed basic science and/or engineering research;
2. Potential for the research, if successful, to significantly advance fundamental understanding in the topic area;
3. DoD potential interest in the proposed research; and
4. Qualifications and availability of the Principal Investigator and other investigators

The following three evaluation criteria are each of lesser importance than any of the above four, but are equal to each other:

5. Adequacy of current or planned facilities and equipment to accomplish the research objectives;
6. 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
7. Realism and reasonableness of cost (cost sharing is not a factor in the evaluation) Decisions for exercising options will be based on accomplishments during the base years and potential research advances during the option years that can impact DoD research priorities and technological capabilities.

2. 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 specialized Government employees secured under the Intergovernmental Personnel Act (IPA). These individuals will sign a conflict of interest and a non-disclosure statement prior to receiving proposal information.

Full proposals will undergo a multi-stage evaluation procedure. The cognizant Program Officer 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. Similarly, support contractors may be utilized to evaluate cost proposals. However, proposal selection and award decisions are solely the responsibility of Government personnel. Each support contractor's employee and advisors external to the US Government having access to technical and cost proposals submitted in response to this FOA 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.

VI. AWARD ADMINISTRATION INFORMATION

1. Administrative Requirements –

System for Award Management (SAM): All Offerors submitting proposals or applications must:

- 1) Be registered in the SAM prior to submission;
- 2) 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 any agency; and
- 3) Provide its DUNS number in each application or proposal it submits to the agency.

The System for Award Management (SAM) is a free web site that consolidates the capabilities you used to find in CCR/FedReg, ORCA, and EPLS. Future phases of SAM will add the capabilities of other systems used in Federal procurement and awards processes. SAM may be accessed at <https://www.sam.gov/portal/public/SAM/>.

2. Reporting

In general, for each grant award, annual reports and a final report are required summarizing the technical progress and accomplishments during the performance period, as well as any other report as requested by the Research Topic Chief.

Access to your Grant

Effective 01 October 2011, hard copies of award/modification documents are no longer mailed to Offerors. All award/modification documents will be available via the Department of Defense (DoD) Electronic Document Access System (EDA).

EDA is a web-based system that provides secure online access, storage, and retrieval of awards and modifications to DoD employees and vendors.

If you do not currently have access to EDA, complete a self-registration request as a “Vendor” via <http://eda.ogden.disa.mil> following the steps below:

- Click "New User Registration" (from the left Menu)
- Click "Begin VENDOR User Registration Process"
- Click "EDA Registration Form" under Username/Password (enter the appropriate data)
- Complete & Submit Registration form

Allow five (5) business days for your registration to be processed. EDA will notify you by email when your account is approved.

Registration questions may be directed to the EDA help desk toll free at 1-866-618-5988, Commercial at 801-605-7095, or via email at cscassig@csd.disa.mil (Subject: EDA Assistance).

Grants, Certification Requirements:

CERTIFICATION REGARDING RESTRICTIONS ON LOBBYING

Grant awards greater than \$100,000, not under Section 845, require a certification of compliance with a national policy mandate concerning lobbying. Grant applicants shall provide this certification by electronic submission of SF424 (R&R) as a part of the electronic proposal submitted via Grants.gov (complete Block 17).

(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 Section 1352, title 31, U.S.C. 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.

REPRESENTATION REGARDING AN UNPAID DELIQUENT TAX LIABILITY OR A FELONY CRIMINAL CONVICTION UNDER ANY FEDERAL LAW - DOD APPROPRIATIONS -

All grant applicants are required to complete the "Representation on Tax Delinquency and Felony Conviction" found at <http://www.onr.navy.mil/Contracts-Grants/submit-proposal/grants-proposal.aspx> by checking the "I agree" box in block 17. and attaching the representation to block 18. of the SF424 (R&R) as part of the electronic proposal submitted via Grants.gov. The representation reads as follows:

(1) The applicant represents that it is ___ is 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

(2) The applicant represents that it is___ is not __a corporation that was convicted of a felony criminal violation under any Federal law within the preceding 24 months.

NOTE: If an applicant responds in the affirmative to either of the above representations, the applicant is ineligible to receive an award unless the 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.

VII. OTHER INFORMATION

1. Use of Animals and Human Subjects in Research

If animals are to be utilized in the research effort proposed, the Offeror must complete a DoD Animal Use Protocol with supporting documentation (copies of AAALAC accreditation and/or NIH assurance, IACUC approval, research literature database searches, and the two most recent USDA inspection reports) prior to award. For assistance with submission of animal research related documents, contact the ONR Animal Use Administrator at (703) 696-4046. For AFOSR, please contact the Human, Animal and DNA Research Protections Officer at (703)588-0664, and e-mail: AFOSRHARPO@us.af.mil. For assistance with submissions to ARO topics contact Bill Bratton, telephone: (919)549-4220, email: bill.e.bratton.ctr@mail.mil,

Similarly, for any proposal for research involving human subjects submitted to an ONR topic, the Offeror must submit or indicate an intention to submit prior to award: documentation of approval from an Institutional Review Board (IRB); IRB-approved research protocol; IRB-approved informed consent form; proof of completed human research training (e.g., training certificate or institutional verification of training); an application for a DoD-Navy Addendum to the Offeror's DHHS-issued Federal wide Assurance (FWA) or the Offeror's DoD-Navy Addendum. In the event that an exemption criterion under 32 CFR.219.101 (b) is claimed, provide documentation of the determination by the Institutional Review Board (IRB) Chair, IRB vice Chair, designated IRB administrator or official of the human research protection program including the category of exemption and short rationale statement. This documentation must be submitted to the ONR Human Research Protection Official (HRPO), by way of the ONR Program Officer. Information about assurance applications and forms can be obtained by contacting ONR_343_contact@navy.mil. If the research is determined by the IRB to be greater than minimal risk, the Offeror also must provide the name and contact information for the independent medical monitor. For assistance with submission of human subject research related documentation, contact the ONR Human Research Protection Official at (703) 696-4046. For submissions to AFOSR topics, please contact the Human, Animal and DNA Research Protections Officer at (703) 588-0664. For submissions to ARO topics, please contact Bill Bratton, telephone: (919)549-4220, email: bill.e.bratton.ctr@mail.mil.

For contracts and orders, the award and execution of the contract, order, or modification to an existing contract or order serves as notification from the Contracting Officer to the Contractor that the HRPO has approved the assurance as appropriate for the research under the Statement of Work and also that the HRPO has reviewed the protocol and accepted the IRB approval or exemption determination for compliance with the DoD Component policies. See, DFARS 252.235-7004.

2. Recombinant DNA

Proposals which call for experiments using recombinant DNA must include documentation of compliance with Department of Human and Health Services (DHHS) recombinant DNA regulations, approval of the Institutional Biosafety Committee (IBC), and copies of the DHHS Approval of the IBC letter.

3. Department of Defense High Performance Computing Program

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

<http://www.hpcmo.hpc.mil/>.

4. Project Meetings and Reviews

Generally an annual program review will be required by the DoD program manager. Other reviews will be held as necessary. Program status reviews are held to provide a forum for reviews of the latest results from experiments and any other incremental progress towards the major demonstrations. These meetings will be held at various sites throughout the country. For costing purposes, offerors should assume that 40% of these meetings will be at or near ONR, Arlington, VA and 60% at other contractor or government facilities. Interim meetings are likely, but if possible these will be accomplished via video telephone conferences, telephone conferences, or via web-based collaboration tools.

5. Military Recruiting On Campus

Military Recruiting on Campus (DoDGARS Part 22.520) applies to domestic U. S. colleges and universities. Appropriate language from 32CFR22.520 Campus access for military recruiting and Reserve Officer Training Corps (ROTC) will be incorporated in all university grant awards.

6. Federal Funding Accounting 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, requires that all agencies establish requirements for recipients reporting information on subawards and executive total compensation as codified in 2 CFR 33.110. Any company, non-profit agency or university that applies for financial assistance (either grants, cooperative agreements or other transaction agreements) as either a prime or sub-recipient under this BAA 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 33.220. An entity is exempt from this requirement UNLESS in the preceding fiscal year it received: a) 80 percent or more of its annual gross revenue in Federal contracts (and subcontracts), loans, grants (and subgrants), and cooperative agreements; b) \$25 million or more in annual gross revenue from Federal contracts (and subcontracts), loans, grants (and subgrants), and cooperative agreements; and c) the public does not have access to information about the compensation of the senior executives through periodic reports filed under section 13(a) or 15(d) of the Securities Exchange Act of 1934 or section 6104 of the Internal Revenue Code of 1986.

7. Organizational Conflicts of Interest:

All prospective offerors and subrecipients shall affirm whether they are providing scientific, engineering, and technical assistance (SETA) or similar support through an active contract or subcontract to the respective technical office(s) upon which a white paper and/or full proposal is submitted. All affirmations must state which office(s) the offeror supports and identify the prime contract number.

Those offerors submitting a white paper are urged to identify the potential conflicts at the time of white paper submission. Affirmations shall be included in the full proposal submission regardless of whether a white paper was submitted.

All facts relevant to the existence or potential existence of organizational conflicts of interest must be disclosed. The disclosure shall include a description of the action the offeror has taken or proposes to take to avoid, neutralize, or mitigate such conflict. Proposals that fail to fully disclose potential conflicts of interests will be rejected without technical evaluation and withdrawn from further consideration for award.

If a prospective offeror believes that any conflict of interest exists or may exist (whether organizational or otherwise), the offeror should promptly raise the issue with the specific agency by sending his/her contact

information and a summary of the potential conflict by e-mail to the Business Point of Contact before time and effort are expended in preparing a proposal and mitigation plan.

If, in the sole opinion of the Business Point of Contact and after full consideration of the circumstances, any conflict situation cannot be effectively avoided, the proposal may be rejected without technical evaluation and withdrawn from further consideration for award under this FoA.

8. Office of Management and Budget (OMB) guidance effective 26 Dec 2014:

Any assistance instrument awarded under this announcement will be governed by the award terms and conditions, which conform to DoD's implementation of OMB circulars applicable to financial assistance. Terms and conditions of new awards and funding increments to existing awards made after December 26, 2014, may include revisions to reflect DoD implementation of new OMB guidance in 2 CFR part 200, "Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards."

Section VIII. MURI TOPICS

ARO FY2015 MURI Topic 1

Emulating the Principles of Impulsive Biological Force Generation

Background: A multitude of organisms across length scales and species have evolved physiological specializations capable of extremely rapid movements. In some cases, forces are generated with accelerations exceeding millions times that of gravity within a matter of nanoseconds—outperforming by orders-of-magnitude our best artificial capacities for rapid and recoverable motion. Among animals, impulsive force generation occurs in a broad range of insects (e.g. fleas, katydids, jumping spiders, and trapjaw ants) while exemplary larger organism actions include mantis and pistol shrimp predation, rapid discharge of jellyfish stinging cells, snake strikes, ballistic tongue projection, crab jumps, and fish and lizard escape maneuvers. Within the plant kingdom examples include the nastic response of carnivorous plants as well as pollination mechanisms. Advances in measurement over the last decade have led to a number of discoveries in biology such as record-breaking speeds, entirely new morphologies, and increased understanding of extreme biological elasticity (e.g. synchronizing planthopper gears, pneumo-hydrostatic crab skeletons, and elastomeric protein composites in froghoppers). The underlying science of impulsive biological force generation, however, has remained fragmentary and synthetic emulation of animal movement has focused on slow, rhythmic dynamics. Lack of understanding has led researchers attempting to artificially achieve impulsive dynamics to pursue irreversible energy conversion, e.g. through detonation of energetic materials. Enabling synthetic emulation of the principles governing impulsive physiological work cycles requires new multidisciplinary approaches toward a general, cohesive framework for characterizing the scaling laws and integrated biological, chemical, and physical system interactions. Fortunately, there have been several recent advances, such as new understanding of the role of chemical transport and propagating action potentials in snap-buckling, that suggest exciting

opportunities to advance system level understanding and novel demonstrations of discovered principles.

Objective: The objective of this MURI is to develop systems-level fundamental understanding of the integrated mechanical, chemical, and electrical principles by which extraordinary energy storage, rapid release, and recovery yield impulsive yet repeatable movements in biology to enable synthetic emulation.

Research Concentration Areas: Suggested research areas include, but are not limited to the following: (1) elucidation, through both theory and experiment, of the component and systems-level principles underlying the work cycles, triggering mechanisms, spontaneity, and recoverability of impulsive physiological engines; (2) delineation of scaling principles in high-speed functional morphology; (3) characterization and predictive modeling of integrated biological, mechanical, chemical, and electrical mechanisms; (4) demonstration of principled understanding of the scaling laws and interactions leading to impulsive energy release and rapid recovery via novel synthetic instantiations.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of \$1.25M per year for five years, supporting no more than six funded faculty researchers. Exceptions should be discussed with the topic chiefs during the white paper phase of the solicitation.

Research Topic Chiefs:

Dr. Samuel Stanton, 919-549-4225, samuel.c.stanton2.civ@mail.mil and

Dr. Robert Kokoska, 919 549 4342, robert.j.kokoska2.civ@mail.mil

ARO FY2015 MURI Topic 2

Exploiting nitrogen vacancy diamonds for manipulation of biological transduction

Background: The nitrogen vacancy center lattice defect in diamond nanoparticles (NV-diamond) is now known to retain activity in biological environments. Current applications of NV-diamond include quantum computing, nanoscale magnetometry, super-resolution imaging and atomic scale magnetic resonance imaging. These state of the art applications involve NV-diamonds implanted in substrates; however recent breakthroughs have allowed isolated nano-diamond particles to be used as biosensing intracellular quantum probes for thermometry and bacterial tracking as well as extracellular quantum probes of ion channel operation. A key reason for NV-diamond sensitivity, including in the emerging biosensing applications, is that the spectral shape and intensity of optical signals from NV-diamond are sensitive to external perturbation by strain, temperature, electric fields and magnetic fields. Biological sensory transduction relies upon highly evolved ion channel-based mechanisms that involve transducing environmental energy into a bioelectrical signal for intercellular communication. The recent demonstrations of NV-diamond's extreme sensitivity and localization now provide new research opportunities for transitioning NV-diamonds from passive sensors to novel biophysical interfaces whose perturbed energy emission can be used as a signal to control or modify sensory transducer molecular physiology and intra- and inter-cellular signaling. Basic scientific efforts required to realize this new regime include interfacing NV-diamonds with transgene-engineered or innate transduction channels for controlling intracellular signaling in living cells. This represents a new multidisciplinary scientific approach whereby the quantum behavior of NV-diamond can be directed to alter living cells by directly engaging biophysical mechanisms to enhance or disrupt cellular function. This effort seeks to realize this important tool and establish an experimental suite that relies upon the emission of photons from NV-diamond to energize biological receptors that trigger activation, disruption or modulation of bioelectrical transduction processes.

Objective: The objective of this MURI is to elucidate the impact of biological environments on the behavior of NV-diamond lattice defects and develop the relevant synthetic chemistries necessary to stably couple NV-diamonds with bioelectrical transduction processes.

Research Concentration Areas: Research concentration areas might include, but are not limited to: (1) reproducible and scalable synthesis of NV-diamond with controlled size, geometry, composition and emission properties; (2) creating stable, quantitative and bio-compatible surface chemistry for NV-diamond; (3) studying perturbative effects of chemical and biological systems on NV-diamond spin coherence; (4) molecular synthesis, expression and characterization of designer exogenous proteins/receptors that respond to novel electromagnetic spectral windows; (5) introducing in-situ and in-vivo control of biological transduction pathways by NV-diamond.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of \$1.25M per year for 5 years, supporting no more than 6 funded faculty researchers (and their teams). 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. Frederick Gregory, ARO, 919-549-4318, frederick.d.gregory5.civ@mail.mil,

Dr. Paul Baker, 919-549-4202, paul.m.baker4.civ@mail.mil

ARO FY2015 MURI Topic 3

Noncommutativity in Interdependent Multimodal Data Analysis

Background: In distributed sensor fusion, wide area surveillance and social network analysis, it is of increasing importance to analyze interdependent multimodal data. The information in such data is typically noncommutative (i.e. not permutation invariant). For example, information flows over a distributed sensor network depend strongly on the partial ordering of edges in the network, e.g., ordered according to shortest paths, community structure, or relative edge importance. The traditional approaches of aggregated univariate modeling do not capture such asymmetric interdependency. The celebrated Shannon's information theory, originally developed for the analysis of terminal-to-terminal data communication without feedback, is not directly applicable. A new formulation of information theory that generalizes Shannon's classic theory is needed to explicitly address such noncommutativity. The generalization should provide methods for characterizing the complexity of asymmetric interdependency to predict the performance of data analysis such as fundamental limits of the extraction of "information" from interdependent data. Recently, directed extensions of classical information theory have been used to develop new tools for the analysis of high dimensional, multimodal, spatiotemporally dependent data. Advances in quantum information theory on noncommutative operators and recent noncommutative extensions of mutual information shed new insights that may be leveraged for data analysis. These advances have opened up a new frontier of data analysis leading to a novel analytical framework that explicitly addresses complex interdependent data from heterogeneous networked sources. Such a framework would provide new methods or algorithms for extracting and fusing information from non-traditional data structures. Some of the major challenges include accounting for effects of multilayered directed dependency, scalability for large-scale real-world networks, and dealing with application-dependent nuisance factors such as variation in illumination, view direction, or scale in visual data.

Objective: To establish an analytical framework of noncommutative information theory for the analysis of interdependent multimodal data from large-scale heterogeneous networked sources. The focus should be placed on laying a foundational work for extracting actionable information from multimodal data such as EO/IR, acoustic, text, or other forms of data.

Research Concentration Areas: Multidisciplinary participation is expected from signal processing, social sciences, statistics and quantum information science. Areas of interest might include, but are not limited to, the following: (1) Create novel concepts of "information" content of data and generalization of Shannon's information theory by capturing the complex dependency structure of multi-source, multimodality data that typically evolve over non-Euclidean spaces; (2) Explore novel approaches to

dimensionality reduction and subspace processing (e.g., collapsing multivariate edge/vertex of a random graph) for statistical or deterministic inference emphasizing on performance robustness and scalability; (3) Establish methods for analyzing spatiotemporal dynamic properties, particularly for understanding dynamic causal systems with feedbacks; (4) Explore approaches to the quantification of distributed information flow over networks in the context of information fusion; (5) Create analytical methods for assessing performance or performance limits of noncommutative information processing.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of \$1.25M 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. Liyi Dai, ARO, (919) 549-4350, liyi.dai.civ@mail.mil;

Dr. T.R. Govindan, ARO, (919) 549-4236,

ARO FY2015 MURI Topic 4

Multi-scale Response for Adaptive Chemical and Material Systems

Background: Living systems are complex systems capable of receiving and using information, interacting with each other and their environment, and performing specific functions in response to stimuli occurring at multiple length and time scales. These sophisticated, innate behaviors are essential for survival, and can be extremely valuable in non-natural systems. A variety of synthetic systems have been engineered to respond to specific stimuli; however, the dynamics of the chemical and material processes and interactions occurring at multiple length and time scales throughout the signal-propagate-response pathway are inadequately understood to rationally design autonomous, “living” systems.

The daunting challenge toward synthetic “living” systems is predictably propagating a molecular level change, generated through the selective sensing of a trigger, into a readily discernible macroscopic change in a material’s fundamental properties. This can only be addressed by developing a fundamental understanding of the chemical processes that occur at multi-scale levels – from molecular to nano to macroscopic length scales and from nanoseconds to hours. The inherent complexity involved in connecting these length scales, and the propagation and amplification of the resulting signals, will require a cohesive, multidisciplinary approach. Separately, a number of approaches have made inroads, which might successfully be combined. For example, work on the depolymerization of polymeric materials has uncovered a strategy to amplify a molecular response to a macroscopic event in the presence of a stimulus. Advances have also been made in analytical techniques that can measure intermolecular interactions, including intermolecular forces at the single molecule level, and the changes in these interactions that are ultimately accountable for a response. Dynamic transmission electron microscopy offers a new platform to image and analyze the transient behavior of chemical reactions and phase transformations with multi-scale spatial and temporal resolution. Sophisticated computational modeling can be used to design materials that demonstrate chemical signaling over macroscopic distances. Finally, predictive theory has been used to design hierarchical assembled structures that exhibit reversible, responsive behavior.

Objective: The objective of this MURI is to develop a fundamental understanding of how to propagate a molecular-level detection event to a macroscopic material property change across multiple length and time scales, and how to connect these multi-scale events and realize signal amplification. Deciphering this basic research challenge will enable design and synthesis of systems that exhibit adaptable, responsive living traits, and possibly emergent properties.

Research Concentration Areas: Suggested research areas include, but are not limited to:

1) Developing strategies to program building blocks and synthetic systems with tailored spatial, temporal, and behavioral properties; 2) Developing strategies to translate signal amplification from the molecular to macroscopic length scale; 3) Developing analytical techniques to monitor and characterize a dynamic system; 4) Developing computational methods to model multi-scale events and dynamic processes; and 5) Designing molecular responses that predictably respond to non-traditional stimuli, a combination of stimuli, and stimuli in complex environments.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of \$1.25M per year for 5 years, supporting no more than 6 funded faculty researchers and their teams. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

Research Topic Chiefs:

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ARO FY2015 MURI Topic 5

New Regimes in Quantum Optics

Background: Quantum optics, particularly in the domain of cavity quantum electrodynamics, provides a pathway to create and use large macroscopic quantum states with photons. Such states have been difficult to generate because atoms trapped in a cavity provide only weak nonlinearity to mediate photon-photon interactions, high photon loss introduces decoherence, low photon collection and detection efficiency decrease success probability, among other challenges. On the other hand, recent progress in superconducting qubits and high-quality microwave cavities for quantum computing has enabled orders of magnitude improvements in coherence, fast single shot high-fidelity readout, high-fidelity quantum operations, low photon loss, and better understanding of decoherence mechanisms. These advances have enabled early experiments that have demonstrated the creation of high-fidelity coherent states with several tens of photons. In addition, the new generation of superconducting devices opens up the opportunity for the exploration of new regimes of quantum optics involving quantum states of 100s of photons. Further advances are possible if, in addition to the physics of quantum optics, advanced microwave circuit engineering is brought to bear on the regime of low-power microwave signals to improve coherence and function, and materials science is employed to determine relationships between decoherence and defects in materials, surface chemistry, and interface quality. In turn, the superconducting systems and the quantum states created in them could also be used as sensitive probes of materials behavior, in particular of the origin and sources of decoherence and dissipation mechanisms. Finally, these superconducting devices and the long-lived macroscopic quantum states they can create offer a pathway to quantum microwave circuits operating in the ultra-low power regime for new functionality in signal processing, sensing and measurement, computing, simulation, and communications.

Objective: The goal of this topic is to (i) exploit recent advances in superconducting devices and microwave photons to explore new regimes in quantum optics not attained with optical photons; (ii) to probe materials characteristics and behavior causing decoherence and dissipation and explore new materials that improve performance and extends the nonlinear quantum optics regime even further; and (iii) to develop a quantum microwave circuit framework that incorporates macroscopic quantum states and provides new functionality.

Research Concentration Areas: Work should advantageously exploit recent progress in superconductor qubit systems to achieve the above objectives. Some research concentration areas for this topic might include: (1) creation and control of large long-lived macroscopic coherent states, topological states,

squeezed states, and other exotic quantum states with large photon number; (2) exploration of the behavior of and interactions between these states; (3) exploration of the quantum/classical boundary as the size of the states increase; (4) coherent conversion between microwave and optical photons to expand the optics regime; (5) new materials, design, and fabrication of superconductors to further extend the optics regime; (6) macroscopic quantum states as a probe of superconducting materials, such as defects, quasiparticles, surface spins, and other surface effects; (7) establishing a quantum microwave circuit framework incorporating superconductor devices, microwave photons, and macroscopic quantum states; and (8) exploring new ultra-low power microwave circuit designs to enable the optimization of long-lived high photon number entangled states and interactions between them. Related quantum computing research is not a focus area for this topic.

US/UK Collaboration: This topic has been designated for potential US/UK collaborative proposals, as noted in section III of the FOA.

Anticipated Resources: Awards to US MURI team members under this topic will total no more than \$1.25M per year for 3 years (with a 2 year option), supporting 4-6 principal and co-principal investigators from US faculties. Awards to teams with a UK collaborative component may be up to \$2.25M (including the UK portion) per year for 3 years (with a 2 year option), supporting a larger number of investigators. It is strongly encouraged to discuss resources and teaming with the topic chief during the white paper phase. Team members should include physicists, materials scientists, and microwave engineers.

Research Topic Chiefs:

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ARO FY2015 MURI Topic 6

Fractional Order Methods for Sharp Interface Flows

Background: There are several scenarios in CFD, crystal growth, shock propagation in solids, and others for which ad hoc formulations have been developed and accepted over time. This topic involves a new way of thinking about and handling stability and sharp interface effects in a variety of such materials. Explicit methods in fluid flows are generally kept in check by dissipating or redistributing energy and/or momentum through the ad hoc addition of “some” artificial viscosity at “several” “nearby” mesh points. This is clearly a nonphysical (and thus fidelity-degrading) artifice that introduces some intentional amount of inaccuracy in order to keep the computation from blowing up. In elastic solids, shock propagation is also generally managed through the addition of artificial viscosity and the many small steps that make up the wave are superposed to construct the smoothed waveform; it is not clear what the effect could be of contact faces and wave interactions that are closer together than the grid resolution. As another phenomenon, sharp interface flows occur in a variety of materials and contexts. In shocked flows in gases, the shock is often only a few mean free paths in thickness, too thin to justify any grid or meshing, and so it is usual to model with a sharp interface and to use a higher order method on each side of the interface in an attempt to achieve faster convergence. The same situation occurs in FSI when considering flow on one side of a flexible boundary or around a flexible membrane; in order to achieve faster convergence, higher degrees of smoothness are assumed in order to apply higher order methods. The physical objection to these is the fact that applying these methods requires one to assume that the flow is more differentiable, or smoother, in the normal direction at the discontinuity; this is a contradiction that cannot be reconciled, and need not be if other alternatives are admitted. The feature of high order methods that makes them attractive is the fact that they are nonlocal operators (at least more nonlocal than lower order derivatives), but there are other nonlocal operators, such as fractional operators, that have also recently proven to work well in modeling and have the advantage of not

enforcing dubious assumptions of smoothness at discontinuities. For example, a recent alternative idea is that we may be able to manage flow instability in at least a more structured manner by using the order of the convective operator as a control knob, by slightly increasing the order from unity to a real order slightly higher, and thus pushing the system slightly toward a more dissipated solution. Another example is in fluid-structure interaction (FSI) or in two-phase flow, especially where boundaries are far from smooth; state of the art often seeks higher accuracy through higher order methods, which paradoxically assume greater smoothness near the discontinuity. An alternative idea is that perhaps the advantage of higher order methods does not derive so much from the increase in order as it does from the nonlocality of the higher order representation; therefore other nonlocal methods may confer advantages without assuming greater smoothness at the interface. Fractional operators are a candidate for including nonlocality; e.g., integer derivative orders can yield a very compact numerical stencil, while non-integer values can yield a very diffuse non-local stencil. Fractional operators are again a candidate to be employed in a modeling sense, yielding nonlocal support by only slightly moving the order off of integer values without the need to assume a many-fold increase in smoothness. These two examples point to the opportunity for fractional order methods to serve as an alternative means of achieving desirable features within CFD applications. The use of fractional operators to advantage in material systems is not new, having been proven in applications such as fractional order filters in signal processing, fractional order controllers in dynamical systems, and in the time-fractional wave equation where the time operator is tuned downward within the open domain (1,2) in order to model waves in dissipative media. The nonlocality of fractional operators also introduces a potentially significant increase in computational load, but recent progress in more efficient matrix methods for fractional order systems is making these methods feasible for use in modeling flows of both Newtonian and non-Newtonian fluids in a variety of applications.

Objective: To investigate methods for fractional and other nonlocal operators to better-model physical processes in convective, sharp-interface, and other flows, to develop this understanding within a 3D CFD framework with emphases to maximize the use of mathematically rigorous formulations and minimize the use of ad hoc formulations.

Research Concentration Areas: The research concentration areas include, but are not limited to, for fluid mechanical systems of choice that span at least flows with a significant convective component, and a 2-phase flow or FSI or free surface component:

- 1) Identify the operators in fluid dynamical models that commonly receive ad hoc/higher order approximations during computation, and investigate the advantages of replacing them by more structured fractional order or other nonlocal operators.
- 2) Identify flow scenarios and features which are amenable to high fidelity modeling via fractional and non-local operator implementations and verify model using empirical data.
- 3) Investigate how the resulting models can be implemented computationally (FD or FEM).
- 4) Investigate the nature and scope of the computational complexity associated with these new models and implementations, and develop new methods to sparsify/precondition/parallelize/distribute the resulting (dense) matrix systems.
- 5) Validate the resulting computational models against current methods, and investigate relative advantages/disadvantages.

Anticipated Resources: It is anticipated that this effort will require no more than \$1.25M per year for 5 years, supporting no more than 6 funded faculty researchers.

Research Topic Chiefs:

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ARO FY2015 MURI Topic 7
2-Dimensional Organic Polymers

Background: Two-dimensional organic polymers (2DOPs) are laterally infinite, one monomer unit thick, covalently bonded, free-standing, crystalline, high aspect ratio nanosheets / covalent organic frameworks (COFs) with well defined internal long range periodicity. In contrast to graphene, novel 2DOPs with extended π - conjugation will have a band gap making them very attractive for future large area, flexible, low power electronic/optoelectronic applications. In addition, the electronic properties of 2DOPs such as band gaps, charge carrier mobilities, and exciton diffusion lengths can be tuned by tailoring the compositions and structures. Unlike the inorganic 2D materials with band gaps (e.g. MoS₂ etc.), 2DOPs offer greatly enhanced flexibility for tuning the properties by tailoring the structure of the molecular building blocks (i.e. monomer), the length of the polymer, type and placement of functional groups (doping), and type of linkages etc. After many years of research effort, only recently a breakthrough in rational synthesis of 2DOPs with long range order was demonstrated. Isolated, free-standing, individual 2DOPs with long range order were created using solid-state photo-polymerization/ exfoliation as well as solution-based approaches. However, critical gaps remain in our understanding of 2DOPs synthesis (2D polymerization, nucleation, error correction, and defect formation etc.) and property determination (polymer physics, materials characterization) of which severely limits our ability to exploit this new emerging class of materials. Recent theoretical studies on π -electron conjugation in two dimensions show that band gap engineering is fundamentally different in 2D polymers than in their 1D, linear polymer analogues. Specifically, HOMO-LUMO gap (HLG) contraction was predicted in 2DOPs with increasing oligomer size, and initial UV photoelectron spectroscopic studies on 2DOPs indicate shifts in the occupied states upon formation of 2D conjugated networks indicating possible HLG contraction. With many available diverse compositions, low synthesis temperatures, increased mechanical flexibility, scalability, the ability to fold or stack to form unique 3D architectures coupled with tunable electronic/optoelectronic and electrochemical properties, novel 2DOPs could have broad impact on many future DoD applications. Developments in 2DOPs could also impact the development of organic/inorganic hybrids with multifunctional properties and 3D architectures with unique properties such as tunable porosity in response to external stimuli (e.g. pH) etc.

Objective: To create stable free-standing single monomer thick novel 2D crystalline organic polymer nanosheets / covalent organic frameworks (COFs) with unprecedented physical properties such as tunable band gaps, high carrier mobility, high specific capacitance etc., and demonstrate multifunctional properties of unique 3D architectures/hybrids of these materials.

Research Concentration Areas: Research concentration areas might include, but are not limited to the following areas: 1) Develop models to guide the design and selection of organic building blocks that would assemble into single monomer thick 2D polymer sheets/2D COFs with extraordinary properties (optoelectronic/electronic/electrochemical etc.) 2) Advance novel synthetic chemistry methods and create novel organic polymer 2D nanosheets/ 2D COFs predicted by theory 3) Implement unique characterization techniques to assist in 2D polymer synthesis and property characterization 4) Establish a paradigm of 3D architectures, heterostructures, hybrid 2D organic/2D inorganic layered structures and investigate their unique multifunctional properties.

Anticipated Resources: It is anticipated that awards under this topic will be no more than an average of \$1.25M per year for 5 years, supporting no more than 6 funded faculty researchers.

Research Topic Chiefs:

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ARO FY2015 MURI Topic 8

Network Science of Teams

Background: Understanding social processes that lead to wise decision making and peak performance is critical for predicting, evaluating and building successful teams. Teams have unique motivations and dynamics that differentiate them from organizations or populations, such that: teams are incentivized to coordinate using collaborative rather than competitive strategies; they typically require most or all members to interact directly, activating social, cognitive and psychological processes (e.g., shared mental models, group think, social norms); interacting individuals with shared goals generate emergent capabilities not predictable by individual skills (e.g., collective intelligence). There is a need to go beyond the current research which has focused on correlative factors; new research will instead 1) establish causality of underlying cognitive and social mechanisms that drive cooperative processes and 2) characterize interactions and co-dependencies that are both endogenous and exogenous to human systems. Findings are critical to understanding effects of stress on these systems, particularly where resources (time, personnel, diversity of skills) are constrained. Improved models will enable strategies to increase resilience and robustness, e.g., manage permanent or temporary loss of leaders/ team members; match team capabilities with mission objectives. Models are needed that integrate multilevel analytic ideas with recent developments in statistical models, e.g., Exponential Random Graph Models (ERGMs). Metrics of cooperation processes and collaborative performance outcomes (interdisciplinary; adaptability) need to be more rigorously refined and better integrated into dynamical models, with processes like group intelligence, shared mental models, and group think specified as consequences of the foundational model. Further, group-level cognition and social theories need to be formalized so they can better inform quantitative models. New research areas have dedicated efforts towards understanding teams suggesting this topic is ripe for exploration while underscoring the lack of unified theories, methods and models; examples include cognitive science work on linguistic-style matching and collective intelligence studies to measure team performance; evaluation of social factors and network topologies to predict scientific collaboration; experimental work in Complexity Leadership & Team Cognition formalizing metrics of leadership and shared mental models; and mathematical developments of multi-mode and multi-level networks (e.g., ERGMs, game theoretic constructs, Hierarchical Linear Models). Strong multidisciplinary efforts are needed to build theoretically driven predictive models that are able to address the unique considerations and capabilities of teams, including social mechanisms (influence, contagion), cooperative strategies (control, flexibility), group mechanisms (shared mental models, distributed decision-making), and shared products (consensus, breakthroughs). DoD needs these insights to increase effectiveness and coordination of units which can ultimately improve the human dimensions of the military.

Objective: Develop fundamental theories and build quantitative models to predict, evaluate and simulate how teams organize, exchange information, create knowledge, influence, adapt, and reach consensus using cooperation and emergent capabilities to optimize performance.

Research Concentration Areas: Interdisciplinary research is needed to link mathematical approaches to social phenomena. Contributory efforts can be performed by researchers of sociology, cognitive science, social psychology, organizational psychology, computational science, statistics, information and political science. Emphasis is needed but not limited to the following: (1) Create a theoretically driven, quantitative analytical framework for decision-making and productivity of collaborative teams; (2) Develop constructs and mechanisms that measure teamwork, such as interdisciplinarity, adaptability, cooperation, to include processes, e.g., turn-taking, cohesion, group intelligence; (3) Build predictive models that consider teams as complex systems that include dependencies, feedback, and emergence of multiple dimensions; (4) Identify or create empirical or simulated data sets for guiding the research and for verification and validation (V&V) of the theory, constructs, and models.

Anticipated Resources: Awards under this topic will average \$1.25M per year for five years, supporting no more than 6 funded faculty researchers. Exceptions considered by topic chief.

Research Topic Chief:

AFOSR FY2015 MURI Topic 9

Exploiting Biological Electromechanics: Using Electromagnetic Energy to Control Biological Systems

Background: Communication within or modulation of biological systems can be achieved by applying external stressors such as temperature, light, electric fields, and mechanical forces. For example, by manipulating the membrane voltage, limb regeneration that normally would not occur has been induced and the physiological structures of organisms have been altered. Infrared laser pulses have been shown to stimulate neurological action potentials, opening the door to indirect communication between machine and biology through sensory pathways. While the mechanism(s) underlying some electromagnetic (EM)-tissue interactions are well studied on the system level (e.g. absorption of light by a chromophore), other fundamental interactions remain unexplained. For instance, research spanning the last 30 years has shown that biological systems, like the human ear, can be electromechanical in nature, possessing hierarchical tissue and cell combinations resulting in piezoelectric-like biological responses. It has been postulated that such electromechanical properties exist at the sub-cellular level, specifically the plasma membrane of excitatory cells, resulting in a unique system optimized for mechanical wave propagation. This “Soliton” like electromechanical signaling in biomembranes has been suggested to be responsible for cellular signal transduction, rather than the long-held ion influx explanation based on the Hodgkin-Huxley theory and could introduce new paradigms in biology.

The lack of understanding of how cells sense EM fields and communicate these signals throughout biological systems limits the development of adaptive biology-based systems. By studying these interactions, we seek to elucidate the underlying fundamental mechanisms so that the electromechanical behavior of biological systems can be exploited to gain better control of biological signaling, enabling new bio-inspired devices that transduce external stimuli. Additionally, by understanding how the EM-field plays a role in the signaling within and between cells, we can begin to selectively stimulate and detect these signals to effectively interface technological devices with biological systems (man-machine interface; DOI: 10.1016/j.tcb.2007.04.007 & DOI:10.1557/mrs2009).

Objective: The objective of this MURI effort is to advance scientific understanding of the interaction of EM energy with biological systems by combining fundamental exploration of electromechanical properties of biological constituents with theoretical modeling efforts and the development of tools designed to detect the role of electromechanics in biological systems.

Research Concentration Areas: This topic seeks to integrate broad areas that explore the interactions of EM with biological systems. Areas include: (1) discovery-based research into the fundamental processes through which biological systems transmits EM-stimulated signals to relay information, including possibilities that neuronal signaling is an thermodynamic-based phenomenon and not purely ion-driven; (2) investigation into ways that external EM stimuli may be used to modulate biological functions, including optical, radio-frequency or short-pulsed electrical sources (3) theoretical modeling efforts, from model dynamics to quantum mechanics, to predict/explain EM and electromechanical properties in biological systems (4) development of bio-electronic tools specifically designed to better understand the subtle interactions of EM energy with biology, such as nanoFET-based technologies to probe within biological components, (5) new molecular and sub-diffraction limited imaging technologies to visualize the interaction and response of biology with applied signals.

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 should be discussed with the topic chief during the white paper phase of the solicitation.

Research Topic Chief:

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AFOSR FY2015 MURI Topic 10

Large Scale Nano-Architecture Formation

Background: One of the long-standing goals of nanotechnologist has been the ability to create centimeter-sized surfaces with complex nanoscale features. The rate of scientific progress is intrinsically tied to how rapidly experiments can be performed and analyzed, thus a new approach is needed to enable nanofabrication with new materials chemistries, which would drastically accelerate scientific discovery in the chemical, biological, and material science communities. This MURI topic is focused on enabling a paradigm shift in nanotechnology by developing new techniques that can be used in a laboratory setting while simultaneously expanding patterning to the cm² scale. Optical lithography is inexpensive and has good throughput, ~10¹¹ pixels/second, works over cm² sized areas, but feature resolution is limited to approximately 50 nm and these systems must be operated in cleanrooms and utilize specialized expensive equipment. In addition, the semiconductor nanofabrication procedures are focused on patterning a narrow range of hard materials, and the processing conditions used are largely incompatible with the soft materials that make up the biological and chemical world. E-beam and scanning probe lithographies, have shown promise, however, each necessitates trades between cost, throughput, and feature size. For example, E-beam lithography while having nanometer feature resolution is both costly and have very limited throughput with fabrication over a 1cm² area taking literally days. In addition these systems are often challenged by placement accuracy because there is no way to determine the actual beam position on the specimen during fabrication. Scanning probe technologies such as dip pen nanolithography have feature resolution down to 10²'s of nanometers, but patterning speed is slow. While scanning probe technologies are capable of operating with registry to existing features they can have difficulty operating on non-uniform surfaces with topology and features; especially with cantilever arrays. New breakthroughs in zone plate lithography, near field optical lithography, and dot matrix nanoprinting have revealed promising approaches to achieving rapid benchtop nanofabrication with feature registration, however, research must be conducted to improve these techniques and broaden their applicability to new material sets. This topic seeks to understand and exploit the underlying scientific principles, which govern nanoscale material properties to enable nanoscale fabrication of both hard and soft materials. It also aims to explore new nanoscale interactions that can be used to influence nanoassembly, which will require the development of new sensing, control, and registration tools to enable precise placement of nanoscale features in relation to preexisting structures.

Objective: The objective of this program is to develop new scientific foundations to enable new nanofabrication technologies, through experimental and modeling results, that can rapidly fabricate nanoscale arrangements of molecules across cm² scales in a laboratory environment. The approach must be capable of generating features and patterns that are aligned with pre-existing patterns and nanostructures using new soft materials, as well as being able to function on non-uniform surfaces with topology and features. This knowledge will enable point-of-use nanofabrication and rapid prototyping critically needed to enable the development of the next generation of nanoscale technologies such as systems where independent features of the printed structure can cooperatively act on a single molecule.

Research Concentration Areas: Suggested research concentration areas include but are not limited to: 1) Development of orthogonal and highly reliable chemistry and nano manufacturing tools that are compatible with soft materials. 2) Development of new soft material precursor chemistries and material architectures. 3) Near-field optical lithography. 4) Zone plate array lithography. 5) Modeling and

simulation of molecular transfer and deposition on surfaces.

Anticipated Resources: It is anticipated that awards under this topic will be no more than \$1.7M per year for 5 years, supporting no more than five 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 POC:

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AFOSR FY2015 MURI Topic 11

Membrane-Based Electronics: Foldable & Adaptable Integrated Circuits

Background: Modern integrated circuitry relies on the precise spatial control of the electrical properties of a substrate. These substrates are typically planar, either rigid (e.g., Si wafers) or flexible (e.g., plastics), but realizing similar functionalities on a materials platform not bound by a planar geometry would enable revolutionary opportunities. A computer or sensor array which is as foldable and transparent as shrink wrap could conform to surfaces as diverse as paper, MEMS or cell membranes, with transformative interaction between these devices and their environments. Moreover, such devices could be cut, stacked and folded into 3D shapes which would be impossible to obtain with a planar geometry. Recent advances in the synthesis and control of atomically-thin materials (e.g., graphene, h-BN, MoS₂) show promise for building fully functional device circuitry a few atoms thick, without any supporting substrate. While electrons are often confined within an interface atop a planar substrate in conventional electronics, in this new concept, the entire membrane would be part of the device. These materials would be highly bendable, stretchable, optically transparent and chemically inert; electrons would be confined to within angstroms of the surface, enabling sensitive electromagnetic interactions with the environment. As the mass of membrane-based devices would be extremely small, relatively weak external stimulation in the form of light, heat, electric field or chemical environment (e.g., pH) could be used to control their shape and morphology, and they could be designed to adapt to changing environments. Because there would be no substrate associated with these ultrathin bendable structures, there is a significant scientific challenge to producing robust mechanical coupling by integrating semiconductor films with covalent or organic materials.

Objective: This topic seeks to develop novel substrate-free, foldable and highly responsive device architectures on atomically-thin membranes where fully functional electronic, optoelectronic and/or sensing circuits are defined within a primarily 2D structure that is flexible and foldable at the atomic scale. It will require the development of material platforms with diverse electronic components (metals, semiconductors insulators and organic materials) that can be integrated into ultrathin membranes, with processing techniques (e.g., cutting, folding, stacking and bonding) to control the membrane's shape in various 3D geometries, as well as wired or wireless communication methods between membrane-based devices and conventional external circuits. In addition, this topic seeks to develop novel membrane-based structures that lead to electronic circuits with extreme bendability, 2D-to-3D convertible circuit arrays, and membrane biosensors conformal to live cells.

Research Concentration Areas: A material platform conducive to membrane-based electronics includes 2D layered materials that can be synthesized on a potentially large scale. Such materials include graphene, h-BN and transition metal dichalcogenides. In addition, emerging 2D materials with novel magnetic, optical and topological properties can be considered. Previously investigated materials such as ultrathin Si, SiN and organic thin films on flexible substrates, while not preferred alone, may be included as an element within a fully integrated system or when it can be connected with a fundamentally different, stable form (e.g., silicene). Key components of this topic are microscopic and macroscopic manipulation strategies customized for membrane-based devices in order to transform them into different

physical shapes with novel functionalities. Two known techniques to create 3D shapes from 2D sheets are origami (paper folding) and kirigami (cut paper), which could be implemented for membrane-based electronics using external control mechanisms such as magnets or optical tweezers. Another essential component is the communication mechanism: these devices should interact with external control or monitoring instruments through electrical, optical, RF, mechanical or other signals.

Anticipated Resources: It is expected that awards under this topic will be no more than an average of \$1.5M per year for five years, supporting no more than six (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. Harold Weinstock, AFOSR/RTD, 703-696-8572, harold.weinstock@us.af.mil;
Dr. Charles Lee, AFOSR/RTD, 703-696-7779, charles.lee.21@us.af.mil.

AFOSR FY2015 MURI Topic 12
Semantics and Structures for Higher-level Quantum Programming Languages

Background: The endeavors towards designing and building quantum computers have flourish in recent years. Many new quantum computing or simulation algorithms have been explored, quantum computing architectures proposed, quantum information and communication protocols discovered. These activities compel exploration of programmability and universality of quantum computing devices as general-purpose machines. Classical computers embody desirable features such as programmability, universality, and high-level control structures. To what extent do quantum computers, if they can be built, possess similar characteristics? To answer this question, this MURI topic addresses some key issues in the design of higher-level quantum programming languages. A higher-level programming language should be independent of architectural implementations of quantum computers, in the same way a high-level programming language designed for classical computers. High-level formalism allows for the possibility of describing and reasoning about quantum systems, algorithms, or phenomena. Even if quantum computers cannot be built, higher-level methods can still be valuable tools for: specifying quantum algorithms or protocols; formally verifying that an implementation procedure satisfies the required specification; analyzing different components in a quantum algorithm or process, particularly, for their “quantumness” and understanding their behaviors.

Objectives: This topic focuses on higher-level quantum programming language and its formal constructs such as: semantics or mathematical, logical framework needed to represent, describe high-level properties of quantum systems and behaviors of quantum processes; analysis of these properties and behaviors; design of abstract data structures. Demonstrable research outcomes on challenging problems relevant to the DoD are highly recommended.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) Semantics and logical constructs for higher-level programming languages and quantum-mechanical notions (superposition, decoherence, entanglement, quantum measurement, etc.); (2) Mathematical models generalizing the classical Hilbert spaces to describe high-level control structures of quantum processes and quantum operations; (3) Syntax, higher-order operations, abstract data structures for higher-level quantum programming; (4) Properties discerning between classical and quantum-mechanical effects in quantum algorithms or quantum processes; (5) Relationships between physical and high-level computational properties, and interpretation of their behaviors.

Anticipated Resources: It is expected that awards under this topic will be no more than an average of \$1.5M per year for five years, supporting no more than six (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:

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AFOSR FY2015 MURI Topic 13

Strong Field Laser Matter Interactions at Mid-Infrared Wavelengths

Background: The steady development of techniques for generating and amplifying ultrashort laser pulses (e.g. mode-locking, chirped pulse amplification (CPA)) have resulted in the constant escalation of the peak powers available from table top pulsed laser systems since their invention. The last two decades alone have witnessed a remarkable six-order-of-magnitude increase in the achieved focused intensity of these systems, currently surpassing 1022 W/cm². The ability to generate such electric fields has enabled researchers to explore a broad range of fundamental interactions of light fields with matter (e.g. strong field atomic physics, above-threshold ionization, harmonic generation, relativistic plasma physics, etc.). The workhorse behind most table-top experimental research on strong-field interactions has been the Titanium:sapphire-based, CPA laser system operating at a fixed near-infrared wavelength of 0.8 μm . The excellent thermal and optical physical properties of the Titanium:sapphire gain medium have made it a ubiquitous source of ultrashort pulses. As a result of its pervasive use, in the last 15 years, strong field laser matter interactions have not been extensively explored outside of this near-infrared spectral range. The laser wavelength, fixed by the choice of gain medium, plays a fundamental, albeit overlooked, role in dictating the laser matter interaction physics. Even at moderate intensity, free electrons submitted to such radiation fields acquire huge average oscillation energies from the laser pulse (i.e. the ponderomotive energy). The attained energy increases as the square of the wavelength (i.e. $\sim \lambda^2$); a five-fold wavelength increase will produce a 25-fold increase in the electron ponderomotive energy. At a typical laser intensity of 1015 W/cm², a wavelength increase from 0.8 μm to 4 μm corresponds to an electron energy increase from 60 eV to 1.5 keV. Using the wavelength as an experimental knob, many strong-field processes whose characteristics depend directly on the ponderomotive energy (e.g. above-threshold ionization, high harmonic generation) can be pushed to unprecedented limits. In the last few years, laser driver architectures based on nonlinear optical processes, such as optical parametric amplification (OPA), have begun to generate intense mid-infrared photons with excellent output characteristics. Recent experiments using long wavelength drivers have demonstrated remarkably energetic interactions resulting in keV-class high harmonic generation (10.1126/science.1218497) and monoenergetic MeV-class proton acceleration (10.1103/PhysRevLett.106.014801). The recent emergence of high intensity, practical laser architectures operating in the mid-infrared (e.g. 1.5 - 5 μm) is poised to open a largely uncharted pathway to explore the wavelength dependence of strong field processes.

Objective: The objective of this MURI is to broadly explore fundamental strong-field interactions driven by intense laser architectures operating in the mid-infrared (e.g. 1.5 - 5 μm).

Research Concentration Areas: The broad exploration of long wavelength strong-field effects represents transformative science with applications to many fundamental, inherently multidisciplinary, areas of atomic, molecular and optical physics. Suggested research areas include but are not limited to: (1) atomic/molecular ionization dynamics, (2) laser pulse filamentation in air, (3) high harmonic generation, (4) laser-based electron/ion acceleration and (5) fundamental research of intense, mid-infrared laser architectures and gain materials.

US/UK Collaboration: This topic has been designated for potential US/UK collaborative proposals

as noted in section III of the FOA.

Anticipated Resources: It is anticipated that awards to US MURI team members will total no more than \$1.5M per year for 5 years, supporting no more than 6 funded researchers from US faculties.

Awards to teams with a UK collaborative component may be up to \$2.5M (including the UK portion) per year for 3 years (with a 2 year option), supporting a larger number of investigators. It is strongly encouraged to discuss resources and teaming with the topic chief during the white paper phase.

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ONR FY 2015 MURI Topic 14

Visual Commonsense for Scene Understanding

Background: The problem of scene understanding from images and video has been the topic of intense research for several decades; yet despite significant progress in certain respects performance of computer vision systems remain far inferior to that of humans. Here by “scene” we mean its spatial layout as well as the objects and actors in the scene, their relationships, and activities and events that take place in the scene. Computer vision approaches have focused primarily on recognizing objects and simple actions using small image patches to train classifiers. These approaches do not take advantage of supporting contextual information in the broader scene, or knowledge of the world, and are thus inefficient, brittle and inaccurate for natural images in particular. For humans, however, scene understanding is a simple task. One reason for this is that humans possess what we call visual commonsense, that is, the ability to rapidly understand complex scenes without much deliberation using their knowledge and contextual reasoning consistent with the available information. To further clarify, by visual commonsense we mean the ability for the computer vision system to quickly infer from single images or video (which are invariably under-specified) credible scene structures, behaviors, actions and events that can take place in the scene.

The working hypothesis is that commonsense reasoning requires broad knowledge about the world beyond the scale of what can be hand-coded. Moreover, visual commonsense may rely on general knowledge, regular properties of the ecological structure of the environment, and principles that are not obvious to humans how to encode. This implies that vision systems must have the ability to learn expressive, scalable and practical knowledge about the world. Even though developing visual commonsense is very challenging, building on recent promising advances in computer vision combined with new conceptual and experimental tools in cognitive science and psychology make it possible to begin to tackle this difficult problem. Many fundamental problems, both conceptual and computational, remain open. These problems include: what are effective methods of learning the broad and complex knowledge about the world; how do we efficiently and reliably make use of massive online sources of visual and non-visual data for learning; how should we represent and organize the varied and broad knowledge which is often uncertain; what are efficient representations of contextual information; how to do rapid inference with uncertain and underspecified image/video data using the stored knowledge?

Objective: The objective is to gain insights from human visual commonsense and develop principles and computational methods for commonsense reasoning that would enable vision systems to understand visual data at levels approaching human performance.

Research Concentration Areas: We envision a multidisciplinary research program with expertise in cognitive science, psychology, computer vision, artificial intelligence, machine learning and

mathematics. Research in commonsense reasoning can be broad; therefore, we want to focus on in-depth investigation of a few scenarios to elucidate commonalities and differences among situations and tasks, and discover biases and approximations that humans use in processing visual data. Suggested research areas include the following. (1) Investigate visual commonsense reasoning in humans: How do humans parse images and videos and reduce the massive visual data to its few essential entities and their relationships and interactions, spatial layout of the scene, activities and events? (2) Develop novel strategies and computational methods for learning the knowledge needed for visual commonsense; methods that are efficient, robust and scalable. Of particular interest are methods for lifelong learning, which would encompass learning with domain knowledge, learning from a few examples, and transfer learning, as well as instruction based learning. (3) Research has shown that knowledge organized in hierarchical and compositional models and expressed at multiple levels and multiple forms appears to be most efficient for storage as well as inference. We want to develop vision system architectures that represent knowledge in such structures; architectures that can support learning and reorganizing visual knowledge optimized for fast inference with uncertain stored knowledge and uncertain, underspecified visual data, and that take into account the structure of ecological information.

US/UK Collaboration: This topic has been designated for potential US/UK collaborative proposals, as noted in section III of the FOA.

Anticipated Resources: It is anticipated that awards to US MURI team members under this topic will total no more than an average of \$1.5M per year for 5 years, supporting no more than 6 funded researchers from US faculties. Awards to teams with a UK collaborative component may be up to \$2.5M (including the UK portion) per year for 3 years (with a 2 year option), supporting a larger number of investigators. It is strongly encouraged to discuss resources and teaming with the topic chief during the white paper phase.

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ONR FY2015 MURI Topic 15

Characterization and Prediction of Remotely Sensed Mesoscale Aerosols in Coastal and Maritime Atmospheric Boundary Layers for Electro-optical Propagation

Background: In short and medium range atmospheric propagation scenarios, optical waves encounter distributed volume scatter and attenuation, as well as refractive and turbulent effects, that are not sufficiently well characterized and make atmospheric mitigation/ correction techniques difficult. In the last decade, great advances have been made in aerosol meteorology and computational science leading to an operational capability for global scale aerosol data assimilation to initialize prognostic models used in remote sensing corrections, atmospheric composition for numerical weather prediction, climate modeling, and air quality. However, understanding of the predictability, length scales and covariance structures needed to downscale these techniques for DoD applications and regional air quality models is not sufficiently advanced. This prevents the development of a prognostic capability at time and space scales suitable for performance prediction of maritime free-space optical communications, imaging sensors, and solid-state laser propagation, as well as ground-based astral observations for precision navigation. Currently there are critical knowledge gaps between locally generated, single-station analysis of propagation conditions from in-situ measurements, with relevant horizontal length scales of meters to a few kilometers, and global scale conditions with length scales of hundreds of kilometers. In fact, the evolution of the atmosphere from land to ocean presents a complex fluid dynamical and thermodynamic

problem in itself.

To close this gap in understanding, an integrated, multidisciplinary approach is needed given the strong coupling in littoral regions between the oceanography, meteorology, and optical wave propagation physics through aerosol scatter, extinction, atmospheric refraction, and turbulent processes. This requires new direct numerical simulation and data assimilation capabilities, new sensing strategies, sensors, and processing techniques, and potentially additional process-oriented field observational activities. The projection of two-dimensional satellite-based remotely sensed variables into three-dimensional structures applied to global scale forecasts of cloud and aerosol effects does not translate well to this problem due to the strong gradients and multi-scale nature of coastal processes and precludes the use of current operational techniques. It is expected that this topic will take advantage of and refine new developments in remote sensing retrieval techniques, co-variance of directly observed variables and non-observed or parameterized relevant variables, and the use of ensemble-based and tangent-linear model capabilities and may involve development of new sensing or computational technologies. The research should be carried out systematically and should consider the co-variance between coastal flow and aerosol growth, transport, and sources/sinks to fully describe the issue and quantify temporal and spatial variability in forecast models, as well as ensemble techniques to assess predictability and under-resolved ranges of values across a critical value for weapon and sensor performance models. There has been no such research effort emphasizing coupled cloud/aerosol/radiative/meteorological processes in the context of the land-sea interface where predictability can theoretically be gained by the presence of topographic and surface-state dynamical forcing and strong diurnal signal. Marine aerosols are particularly hard to measure accurately because of their hygroscopicity of salt aerosols and complex evolution of biogenic sources.

Objective: The objectives of this MURI are to develop suitable data assimilation techniques to extend satellite remote sensing observations of aerosol optical depth and atmospheric composition into the 5-100 kilometer scale, relevant to the time evolution of attenuation and scatter at optical and infrared wavelengths for propagation through the coastal atmospheric boundary layer and lower troposphere. These data assimilation methods will then be assessed for initialization of Navy predictive models at spatial scales on the order of one to ten kilometers for regions of influence to order 100 km and temporal scales on the order of 1-3 hours for predictions with lead times out to 48 hours. This assessment should reveal and assess fundamental observability barriers to characterizing the littoral electro-optical (EO) propagation environment, followed by an even deeper analysis on cloud, aerosol, and optical turbulence predictability. The focus of this MURI is on environmental phenomenology that could be exploited to enable further exploration of cloud and aerosol effects and how they co-vary with the background meteorology and oceanography which have relatively better predictability. Ultimately this MURI will seek to connect the science of the air-sea-land interface to boundary layer EO propagation.

Research Concentration Areas: Within the framework described above, specific areas include theoretical/computational geophysical fluid and particle dynamics, environmental remote sensing satellite techniques, environmental process studies and data assimilation, potentially laboratory measurements of relevant phenomena, and simultaneous high resolution field measurements of marine boundary layer parameters, aerosol species and concentration, and electro-optical propagation fields.

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.

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ONR FY2015 MURI Topic 16

Role of the Host Microbiome on Behavior/Resilience in Response to Stressors

Background: Humans are colonized by thousands of microbial species that live in and on our bodies. The number of microbial cells outnumbers human cells 10-to-1, and more importantly, the human-associated microbial genome has 150 times more genes than our human genome. The commensal bacteria, fungi and viruses that comprise the gut microbiome (GM), have been shown to have tremendous influence on development of the brain, central and enteric nervous systems, mucosal immune system and protection against pathogens, perception of pain; extraction of nutrients from food and distribution of fat; as well as playing a direct role in several diseases. It is thus critically important to enhance our understanding of this ‘microbial organ’ with a focus on its role in response to external stressors that can affect human resilience. A specific role for GM in emotional behavior; anxiety; memory and cognitive function; and neuromodulator expression has been documented, although primarily in animals. These data are intriguing and support a definite role for the GM in bi-directional signaling via the gut-brain-axis, the hippocampal-pituitary axis, and for overall homeostasis. Of particular interest is the study of behavioral stressors (e.g., fear, anxiety, social crowding) and environmental stressors (e.g., extreme environmental shifts, sleep-deprivation, disrupted circadian cycle), to begin to functionally link specific microbes to observed host responses. Increased understanding of the role of the GM in host response to such stressors will inform new strategies for preventing or attenuating stress effects, and potentially for improving cognitive performance.

Objectives: The objective of this topic is to understand the effects of certain environmental and behavioral stressors on a host and its gut microbiota (GM), with an emphasis on deducing the role the GM may play in mediating psychological, cognitive and physiological effects of such exposures. As stated above, there is tantalizing evidence that the GM plays a pivotal role as an interface between the neurological, behavioral and metabolic well-being of the host. Ideally studies will capture changes at multiple scales, e.g., from the molecular level through cellular/tissue/organ to host physiology, behavior and cognition, and at various time points.

Research Concentration Areas: Suggested research areas include: (1) characterization of the psychological, physiological and cognitive responses of a host and its GM (ideally from molecular to organism/population level) following exposure to various behavioral and environmental stressors, such as: extreme/rapid environmental shifts (e.g., altitudinal, temperature, noise), anticipatory anxiety or fear; disrupted circadian cycles/sleep deprivation; (2) determining if specific GM, metabolites/hormones/neuromodulatory factors or functions play a role in the observed host response to the stressor(s) listed above. Of particular interest is the ‘gut-microbe-brain axis’ and hippocampal-pituitary-axis routes of signaling; and (3) development of novel tools for real-time analysis of microbes, the surfaces they adhere to, and microbial products in the GI tract, to more closely map microbial heterogeneity and identify specific links to their function (e.g., a modified “pill” camera).

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 to 7 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

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ONR FY2015 MURI Topic 17

Metalloid Cluster Networks

Background: Recent discoveries in nano-science synthesis and characterization have yielded metalloid cluster structures that possess material and chemical properties characteristic of both metallic and organometallic materials. Metalloid clusters are defined as a molecular ensemble containing a small number of core metal atoms bonded only to other metal atoms, contained within a shell of metal atoms bonded to organic ligands. The outer layer of ligands provides a protecting shell stabilizing the cluster. As the number of core metal atoms increases, electronic, magnetic and optical properties vary greatly, due to quantum confinement effects. Furthermore, it may be possible to predict and control these emergent properties. Metalloid clusters containing approximately 10-200 total metal atoms are of fundamental scientific interest as their properties encompass the behavior of organometallic materials with discrete energy levels and the conductive nature of the confined metal core.

A revolutionary potential for metalloid clusters is their use as building blocks to afford complex composite cluster networks, which can have dimensions typical of bulk materials (>100 nm), yet retain properties unique to their smaller scale components (1-10 nm). Locking the highly reactive clusters into three dimensional assemblies will stabilize the cluster, while providing an ability to alter the underlining physical and chemical properties of the metal core through the application of electric or magnetic fields. This may allow meta-material behavior that can be tuned or altered as desired. Properties not normally associated with metallic materials may be achievable, including tunable hardness, transparency, thermal, magnetic and electrical behaviors.

Metalloid cluster material science is at the cutting edge between molecular and solid-state chemistry, however progress has been limited by difficulties with synthesis, material characterization and prediction of metalloid cluster structure-property relationships. Simple, effective theories, comparable to the isolobal principle used with organometallic systems, must be developed for metalloid cluster science. This MURI will develop fundamental theoretical understanding of metalloid cluster properties allowing effective approaches to their design and construction, i.e., computer-aided materials design.

Objective: Discover and define fundamental properties of new metalloid clusters containing metal atoms in low oxidation states and having unique structural, chemical, electronic, and magnetic configurations that are stable enough to incorporate into higher dimensional solid-state network materials. Establish design scope, synthesis pathways, and property characteristics of metalloid clusters and their networks.

Research Concentration Areas: To clearly understand cluster properties, suggested research areas include, but are not limited to: (1) Computational approaches leading to: (i) the design of optimal large cluster structures, (ii) the prediction of cluster magnetic moments on atomic substitution and cluster passivation, (iii) quantitative structure-property relationships (QSPR), (iv) the interpretation of experimental measurements of cluster stability and oxidation resistance; (2) Structure-property relationships between metalloid clusters and the subsequent potential for cluster derived nano-material lattice system design, and property characterization; and (3) Experimental efforts focused on the optimization of gas-phase and condensed phase cluster synthesis, characterization, and isolation techniques. This research will encompass theoretical, experimental, and diagnostic approaches within physics, chemistry, and material sciences.

Anticipated Resources: Awards under this topic will not exceed an average of \$1.5M/year for 5 years, supporting 4 to 6 faculty researchers. Exceptions warranted by specific proposed approaches should be discussed with the topic chief during the white paper phase of the solicitation.

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ONR FY2015 MURI Topic 18

Computational and Experimental Methods towards Understanding the Chemistry and Physics of Materials over 2000°C

Background: In the last decade, the interest and research on ultra-high-temperature materials for hypersonic vehicle and weapon applications has increased dramatically in the US and worldwide. However, progress is hampered by limitations in understanding, predicting and modeling chemical bonding, high-temperature phase diagrams, microstructural evolution and related structural and chemical stability under the extreme conditions. Recent advances in theoretical tools to calculate electron density distribution and bond structure in these complex materials at realistic formation temperatures will allow development of urgently needed phase diagrams leading to materials discovery. Computational tools to predict physical properties and chemically- and thermally-activated responses to extreme temperature, stress and oxidative environments will enable both the identification and prediction of promising compounds – and provide crucial insight for developing advanced testing techniques and interpreting the unavoidably complicated experimental results.

Objective: The objective of this MURI is to provide a fundamental understanding of the chemistry and physics of materials in extreme environments, particularly at temperatures above 2000°C. It is divided in to 2 major areas: a) theoretical understanding of the nature of the bonding and crystal structure as they relate to the melting behavior, thermal, and mechanical behavior, and the use of this knowledge to create new compounds with improved properties, and b) the understanding of thermally activated events including diffusion mechanisms, microstructure evolution, and thermally-induced chemistries at these temperatures as they relate to solid-solid interactions and oxidation to improve prolonged high-temperature applications. In this MURI, we seek to develop rationale design strategies based on scientific principles rather than relying upon informed intuition and require the use of theory for interpretation of experimental results. Using quantum theories we seek a fundamental understanding of the electronic structure of known ultra-high temperature materials, especially the topological features of electron density gradients, i.e., Bader analyses, within those materials. High-throughput screening and informatics approaches should be used to find alternative compositions having similar topological networks of chemical bonding. Computational thermodynamics will be used to predict phase diagrams of those complex multicomponent systems, and validation of those predictions will be done experimentally. ICME principles are de rigueur.

Research Concentration Areas: A balanced, interdisciplinary program consisting of: (1) computational materials science; (2) materials synthesis and characterization; (3) calorimetry and phase diagram development, e.g., CALPHAD; (4) in operando testing methods.

Anticipated Resources: It is anticipated that awards under this topic will be no more than \$1.5M per year for 5 years, supporting 6 to 7 funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation.

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ONR FY2015 MURI TOPIC #19

Quantum Optomechanics

Background: The relationship between the quantum world - governed by principles of quantum state superposition, interference and entanglement – and the classical world of deterministic measurement has

been a subject of speculation for nearly a century. During the past twenty-five years, developments in quantum state preparation, control and readout have led to impressive advances in demonstrations of “quantum logic” i.e. functional devices with no classical counterparts, such as quantum logic-enabled atomic clocks and generators of random numbers certified by Bell inequality violations. Those advances have been primarily in the domain of atomic, molecular and optical physics. There has recently emerged a new field in which intrinsic quantum effects are being explored: the interaction of nanomechanical oscillators with light. Such systems show promise as general-purpose translators of quantum state information between different platforms. For example, one can imagine a single electron spin, such as found in a diamond NV defect, interacting via a magnetized cantilever with an optical cavity, thereby transferring quantum state information to light, which could in turn transfer it to cold trapped atoms or quantum dots. This topic seeks development of hybrid optomechanical systems that connect different quantum information platforms to create demonstration devices of novel functionality.

Objective: The main qubit systems of interest in present quantum information science are photons, trapped ions and atoms, superconducting qubits, solid-state qubits such as spin and defect systems, and nanomechanical oscillators. The objective of this topic is to further exploit the intrinsically quantum behavior of nanomechanical systems, either by: integrating them with other proven systems, such as those named above, to demonstrate new or improved quantum logic operations; or by beating the limits of current techniques in precision measurements relevant to sensing, e.g. by creation of non-classical states of mechanical motion to increase the precision of position measurements; or by transformational improvements in experimental tests of foundational quantum mechanics of macroscopic systems, which could discriminate between different theories of the origins of decoherence and so improve our understanding of the macroscopic limits to implementation of quantum logic.

Note: A recent overview can be found in “Cavity Optomechanics,” M. Aspelmeyer, T. J. Kippenberg and F. Marquardt, <http://arxiv.org/abs/1303.0733> (March 2013)

Research Concentration Areas: The program objectives necessarily require expertise drawn from the two DoD priority themes of quantum information and control and nano-science and nano-engineering. It is probable that the most competitive proposals will engage frontier expertise in both the fabrication and control of nanomechanical systems and an area of applied quantum information science similar to those named above. Materials science and control engineering are among other disciplines that could make important contributions in this area. DoD interest in this topic derives from its prospective importance to missions such as navigation, timekeeping and sensing; and to its implications for the development of practical macroscopic systems for quantum computing and communication. The MURI research is not expected to result in the development of any specific fieldable device, but demonstration of laboratory capabilities that could be extended to DoD missions are particularly encouraged.

Anticipated Resources: It is anticipated that \$1.5M/year will be available for three years plus two additional option years.

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