ONR BAA Announcement Number: ONRBAA13-022

BROAD AGENCY ANNOUNCEMENT (BAA)

Fiscal Year (FY) 2014 Department of Defense Multidisciplinary Research Program of the University Research Initiative

INTRODUCTION:

This publication constitutes a Broad Agency Announcement (BAA) 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 BAA 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 BAA. 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.

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

I. GENERAL INFORMATION

1. Agency Name

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

2. Research Opportunity Title

Multidisciplinary University Research Initiative (MURI)

3. Program Name

Fiscal Year (FY) 2014 Department of Defense Multidisciplinary Research Program of the University Research Initiative

4. Research Opportunity Number

ONRBAA13-022

5. Response Date

White Papers: 15 October 2013

Full Proposals: 16 December 2013

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 2014 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 BAA. 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. Attosecond Electron Dynamics
2. Force-Activated Synthetic Biology
3. Nonlinear Dynamics of Energy Hypersurfaces Governing Reaction Networks
4. Strongly Linked Multiscale Models for Predicting Novel Functional Materials
5. Multistep Catalysis
6. Innovation in Prokaryotic Evolution
7. Ultracold Molecular Ion Reactions
8. The Skin-Microbe Interactome

White papers and Full proposals addressing the following topics 9 through 17 should be submitted to the Air Force Office of Scientific Research (AFOSR):

9. Time-resolved quantum dynamics of complex systems
10. Computational Foundation of Mathematics and Information
11. Transport and Utilization of Energy Using Plasmon-induced Processes
12. Design Rules for Biobased and Bioinspired Materials
13. Control of Coherent Structures in Plasmas for Reconfigurable Metamaterial-Based Devices
14. Multifunctional Quantum Transduction of Photons, Electrons and Phonons
15. Control of Light Propagation through Metasurfaces
16. Goal-Driven, Multi-Source Algorithms for Complex Resilient Multi-Physics Systems
17. Security Theory of Nano-Scale Devices

White papers and full proposals addressing the following topics 18 through 24 should be submitted to The Office of Naval Research:

18. Understanding Energy Harvesting Mechanisms in Polymer-Based Photovoltaics
19. Role of Bidirectional Computation in Visual Scene Analysis
20. Exploring the Atomic and Electronic Structure of Materials to Predict Functional Material Properties
21. Optical Computing
22. Quantum optomechanics
23. Air-Sea Interaction and RF Propagation in Maritime Atmospheric Boundary Layers
24. Hydrodynamics of Non-traditional Propulsion

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.

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 BAA.

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. Bill Lukens MURI Program Manager
Office of Naval Research, Code 03R
E-mail Address: william.lukens1@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 the cognizant Contract Specialist, as specified below:

Primary:
Lynn Christian
Contract and Grants Awards Management, Code ONR 0251
Office of Naval Research
875 North Randolph Street, Suite W1275
Arlington, VA 22203-1995
E-Mail:Lynn.christian@navy.mil

Second:
Vera M. Carroll
Acquisition Branch Head
Contract and Grants Awards Management, Code 0251
Office of Naval Research
875 North Randolph Street, Suite 1279
Arlington VA, 22203-1995
E-mail: vera.carroll@navy.mil

Questions submitted within 2 weeks prior to a deadline 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 BAA 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 Broad Agency Announcement (BAA) Webpage – http://www.onr.navy.mil/Contracts-Grants/Funding-Opportunities/Broad-Agency-Announcements.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)

11. Other Information

The Non-ONR Agency Information:

AFOSR
875 North Randolph Street
Suite 325 Room 3112
Arlington, VA 22203-1768

Army Research Office
4300 S. Miami Blvd.
Durham, NC 27703-9142

Work funded under this BAA 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 BAA is estimated to be approximately $250 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. The amount of the award and the number of supported researchers may 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

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 BAA. 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.

Awards under this BAA will be made only to U.S. Institutions of Higher Education which award degrees in science and/or engineering. Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs) are encouraged to submit proposals and join others in submitting proposals. However, no portion of this BAA will be set aside for HBCU and MI participation.

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 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 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

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 Tuesday, 15 October 2013.

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 Tuesday, 29 October 2013.

Submission of Full Proposal:

Any Offeror may submit a full proposal even if its white paper was not identified as being of "particular value" to the Government. 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 BAA are expected to address unclassified basic research. White papers and full proposal submissions will be protected from unauthorized disclosure in accordance with applicable law 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 BAA 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

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 five of this announcement) and the funding opportunity number, designated as “research opportunity number” on page two of this BAA. 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.

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 foraward, 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. 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.

<u>The Following Formatting Rules Apply for Field 8</u>

- 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, andcurriculum vitae are excluded from the page limitations. Full proposals exceeding the page limit may not be evaluated.

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 inprograms 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 studentsand 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 thePrincipal 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) 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 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.

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 01 July 2014. 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 subrecipients. For each subaward, a detailed cost proposal is required tobe included in the principal investigator's cost proposal. Fee/profit is unallowable on subawards.

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).

NOTE: If the grant proposal is for a conference workshop or symposium the proposal should include the following statement. "The funds provided by ONR will not be used for food or beverages".

Fee Profit – Fee/Profit is unallowable.

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 at http://www.grants.gov/web/applicants/organization-registration.html which 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**	01 October 2013*	2:00PM Eastern Daylight Time
White Papers Due	15 October 2013	4:00 PM Eastern Daylight Time
Notification of Initial DoD Evaluations of White Papers	29 October 2013	
Questions Regarding **full proposals**	02 December 2013 *	2:00PM Eastern Standard Time
Full Proposals Due	16 December 2013	4:00 PM Eastern Standard Time
Notification of Selection for Award	8 April 2014 **	
Start Date of Grant	1 July 2014 **	

*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 BAA 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

a. For ARO, use the following alternative to submitting proposals to grants.gov.

Email your completed proposal package and grants.gov trouble ticket/case number to aro.baa@mail.mil. Your proposal must include all signatures and attachments and be submitted in PDF format. All proposal submissions will be subsequently evaluated by ARO for completeness and an official email confirmation will be sent. Incomplete packages will not be considered for an award. All submissions must meet the deadline for full proposals specified in the BAA.

b. For AFOSR submissions please email your completed proposal package and grants.gov trouble ticket/case number to proposal@afosr.af.mil. Each email may not exceed 35MB. If necessary, use multiple emails sending the full proposal noting the trouble ticket/case number. Your proposal must include all signatures and attachments and be submitted in PDF format. An auto-reply email will be returned to the sender indicating that your email arrived. All proposal submissions will be subsequently evaluated by AFOSR for completeness and an official email confirmation will be sent. Incomplete packages will not be considered for an award. All submissions must meet the deadline for full proposals specified in the BAA.

c. There is no alternative process for ONR. Full proposals must be submitted through grants.gov.

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)):

U.S. Army Research Office (FY14 MURI)
P. O. Box 12211
Research Triangle Park, NC 27709-2211

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

U.S. Army Research Office (FY14 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 (17) 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 (18) to (24) 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. William LukensEmail:
William.lukens1@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 BAA 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 papers 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 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 peers from the university community 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 peer from the university community having access to technical and cost proposals submitted in response to this BAA will be required to sign a non-disclosure 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 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/

NOTE TO FORMER CCR REGISTRANTS: If you had an active record in CCR, you have an active record in SAM. You do not need to do anything in SAM at this time, unless a change in your business circumstances requires a change in SAM in order for you to be paid or to receive an award. SAM will send notifications to the registered user via email 60, 30, and 15 days prior to expiration of the record. You can search for registered entities in SAM by typing the DUNS number or business name into the search box.

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 ONR 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:

i. 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. Government Property/Government Furnished Equipment (GFE) and Facilities

Government research facilities and operational military units are available and should be considered as potential government-furnished equipment/facilities. These facilities and resources are of high value and some are in constant demand by multiple programs. It is unlikely that all facilities would be used for any one specific program. The use of these facilities and resources will be negotiated as the program unfolds. Offerors should explain as part of their proposals which of these facilities are critical for the project's success.

2. 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. AFOSR Human Research Protection Official is Ms Stephanie Bruce and her phone number is (703)588-0664, and e-mail: Stephanie.bruce@afos.af.mil

Similarly, for any proposal for research involving human subjects, 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 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.

3. 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.

4. 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/.

5. 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.

6. 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.

52.222-54

7. Other Guidance, Instructions and Information

None

VIII. SPECIFIC MURI TOPICS

ARO FY2014 MURI TOPIC #1

Submit white papers and proposal to Army Research Office

Attosecond Electron Dynamics

Background: Attosecond dynamics is a new field of scientific investigation which allows one to examine dynamics phenomena on the natural timescale of electronic processes in atoms, molecules, and materials. The timescale of microscopic dynamics in quantum systems goes as $\Delta t \sim (\hbar/\Delta W)$; namely it is inversely proportional to the spacing (ΔW) of the energy levels making up the wave packet in a confining potential. For example, ionization of the hydrogen atom requires 13.6 eV and is predicted to occur in a time interval of about 50 attoseconds. Less energetic processes, such as valence electronic transitions in molecules and in semi-conductor materials which occur in the few electron-volt range, have time-scales on the order of 100 – 1000 attoseconds. A recent scientific breakthrough known as double optical gating has lead to the production of broadband laser pulse widths as short as 67 attoseconds, making direct observation of a variety of electronic phenomena possible in real time. Moreover, these attosecond sources are available in table-top format and when combined with the double optical gating technique, they can produce pulses robustly from high-order harmonic generation in the 67 – 500 attosecond range. Thus, now there exist opportunities to examine a variety of electron-dynamics phenomena that arise from electronic motions in molecules on the attosecond timescale. New scientific research opportunities exist in the following: probing excited-state molecular dynamics phenomena with respect to the role conical intersections play in determining chemical branching pathways for photo-dissociation reactions, study of electronic coherent superpositions in both atoms and molecules as a result of simultaneous excitation of multiple electronic states, and development of theories to interpret chemical reactions when the Born-Oppenheimer approximation is no longer valid (e.g., nearly degenerate electronic states).

Objective: The objective of this MURI is to harness attosecond pulses of electromagnetic energy to probe matter (atoms, molecules, plasmas, etc.) at attosecond time scales for real-time observation, control, and understanding of electronic motion in atoms, molecules, and materials.

Research Concentration Areas: Novel research is sought that will lead for the first time to direct observation of dynamics phenomena, including chemistry, occurring in atoms, molecules (including ions), and materials on the attosecond timescale. Suggested research areas may include, but are not limited to, the following: 1.) Implement attosecond transient absorption to probe electronic dynamics in atoms and molecules which arise upon broadband excitation, to include formation of electronic coherent superpositions, and the resulting implications for chemical reactivity from these superposition states; 2.) Devise methods to study molecular dynamics phenomena such as chemical product branching and to quantitatively understand how conical intersections (regions of the potential where two repulsive electronic states become degenerate) influence the reaction outcome; 3.) Develop the techniques and instruments to robustly measure dynamics phenomena at time-scales below 100 attoseconds; 4.) Increase the available flux of isolated attosecond pulses from 10^6 photons/pulse to expected levels (10^7 – 10^8 photons/pulse) that will allow a wider variety of attosecond dynamics phenomena to be studied; 5.) Study plasmon formation, transport, and decay

processes semiconductors and metals.

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 seven 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. James Parker, ARO, 919-549-4293, james.k.parker30.civ@mail.mil
Dr. Rich Hammond, ARO, 919-549-4313, richard.t.hammond10.civ@mail.mil

ARO FY2014 MURI TOPIC #2

Submit white papers and proposal to Army Research Office

Force-Activated Synthetic Biology

Background: A critical aspect of synthetic biology systems is the targeted and controlled activation of molecules affecting biological function. Molecules can be activated by a variety of different signals, including chemical, optical and electrical stimuli, and synthetic biological circuits responsive to each of these stimuli have been successfully assembled. In recent years, the ability of mechanical force to serve as a biological signal has emerged as a unique and unexpected facet to biological activation. The rapidly growing field of mechanotransduction is beginning to reveal an extraordinary diversity of mechanisms by which mechanical forces are converted into biological activity, and which have never been incorporated into advanced synthetic materials. In particular, key molecules governing sensing and transmission of extracellular forces to the interior of the cell have been identified, and several unique mechanisms by which intracellular molecules may alter their function in response to force have been proposed. For example, recent work has revealed a dynamic force sensing mechanism within a protein that forms a critical bridge between the cytoskeleton and the cell membrane, providing unique insights into both the pathways and the temporal nature of mechanotransduction. Concurrently, in materials science, single molecule microscopy and force spectroscopy techniques now provide a wide range of experimental tools to elucidate complex mechanotransduction pathways in synthetic and biological materials. Enhanced control over molecular architectures and assembly now offer several possible approaches to reproduce mechanotransduction mechanisms synthetically. Also, new computational methods enable the coupling of electronic and nuclear dynamics to conformational, structural, and flow dynamics to predict biochemical activity during complex molecular interactions and even motion. These advances provide an exceptional opportunity to integrate biological activation by mechanical force into the growing toolbox of synthetic biology, and to establish unprecedented paradigms for the incorporation of highly specific force activation and response into new materials. A successful effort will demonstrate a powerful new control regime with the potential to dramatically impact engineered biological systems, materials synthesis and fabrication, and force-responsive and adaptive bio-mimetic material systems.

Objective: The objective of this MURI is to elucidate the molecular mechanisms by which living cells regulate intracellular biochemical activity with mechanical force, to reproduce and analyze these force-activated phenomena in synthetic and virtual materials, and to design and exploit optimized synthetic pathways with force-activated control.

Research Concentration Areas: Suggested research areas include, but are not limited to: 1) Elucidation of the mechanisms by which intracellular biological force-responsive molecules are activated and tuned to respond to highly specific forces (i.e., dependent upon duration, strength, frequency, etc.). 2) Coupled predictive modeling and comprehensive characterization of virtual and synthetic materials designed to reproduce biological mechanisms of force-activation. 3) Design and optimization of material substrates through which force can be targeted to anchored force-responsive biological and synthetic molecules. 4) Demonstration of force-activated control in optimized synthetic biological pathways and novel hybrid materials.

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

Research Topic Chiefs: Dr. Stephanie McElhinny, ARO, 919-549-4240, stephanie.a.mcelhinny.civ@mail.mil; Dr. David Stepp, ARO, 919-549-4329, david.m.stepp.civ@mail.mil

ARO FY2014 MURI TOPIC #3

Submit white papers and proposal to Army Research Office

Nonlinear Dynamics of Energy Hypersurfaces Governing Reaction Networks

Background: Kinetic phenomena of DoD interest, from physicochemical and biological reaction networks to quantum many-body phenomena, are typically nonlinear, stochastic, very high-dimensional, strongly interacting, and sustained far-from-equilibrium by extreme variations in intensive properties. Such systems present foremost challenges to both our fundamental understanding and modern computational modeling capabilities. For example, the physics and chemistry underlying combustion stems from a complex, evolving network of tens of thousands of reactions across order-of-magnitude variations in temperature, pressure, and timescale.. The local and global dynamics of reaction networks such as those that emerge in combustion processes are determined by poorly understood dynamics on high-dimensional energy hypersurfaces.These energy hypersurfaces for open systems also spatiotemporally fluctuate and evolve, making the ensuing nonlinear dynamics of reaction coordinates an even greater challenge. Recent advances in modeling energy hypersurfaces are enabling researchers for the first time to accurately calculate typical rate constants and predict species migration for low-dimensional reacting systems. However, new approaches are necessary to understand more realistic kinetic phenomena. Owing to the extreme high-dimensionality and heterogeneity of energy hypersurfaces of reacting systems, elucidating unifying principles governing their nonlinear dynamics poses a significant challenge. Reaction network dynamics on energy hypersurfaces exhibit features of both ergodic systems (with undiscovered invariant, stability, and mixing properties) and complex networks (wherein the conformation space of reaction coordinates is partitioned into intensive and extensive parametric dependent networks of attractor basins and bifurcation pathways). Mathematical advances joining operator and graph theoretic methods for the analysis of high-dimensional nonlinear systems as well as an influx of progress in the physics of complex networks provide strong impetus for developing rigorous predictive understanding of the nonlinear behavior of complex reaction networks on energy hypersurfaces.

Objective: Develop new approaches to predictive models for complex, reacting systems. Develop supporting fundamental theory, perform supporting experiments, and validate resultant models or methods. The goal is to develop computationally efficient, predictive, accurate, robust methods to predict the molecular energy hypersurface, as well as relevant pathways and bifurcation topology for reacting coordinates. A successful effort will result in a method or model that is not based on traditional kinetics models but which can accurately predict (in a computationally efficient manner), outside of its initially validated regime, a reacting system's most relevant reaction pathways and species.

Research Concentration Areas: Suggested research areas include, but are not limited to the following: (1) First-principles-based modeling from quantum molecular theory, (2) Modeling of hypersurface distortion in response to state and system changes, (3) Approaches to link movement along the hypersurface with complex systems theories, (4) Developing mathematical methods for the dynamics of states and/or operators, mixing, attractor formation, bifurcations, etc., upon very high-dimensional hypersurfaces, (5) Integration of dynamically evolving interactions across a complex

network, (6) Evaluation of the stochastic dynamics and global uncertainty propagation, (7) Development of experimental techniques for high spatial/temporal resolution, (8) Development of new computational methods for resultant theories.

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. Ralph Anthenien, ARO, 919-549-4317
ralph.a.anthenien2.civ@mail.mil; Dr. Samuel Stanton, ARO, 410-278-7777,
samuel.c.stanton2.civ@mail.mil

ARO FY2014 MURI TOPIC #4

Submit white papers and proposal to Army Research Office

Strongly Linked Multiscale Models for Predicting Novel Functional Materials

Background: The properties of functional materials are typically influenced by factors such as microstructure, composition, defects, interfaces, strain, and others. Multiscale modeling involving such factors may help to design and discover novel perovskite materials, mismatched alloy semiconductor materials, and 2D nanomaterials with unprecedented functional properties. Current research has not moved beyond weak dependence between continuum and atomistic models. In commonly used weakly linked multiscale models, a macroscale exerts at most a homogeneous influence on a greatly separated finer scale and lacks constitutive properties, which are supplied by reaching down to the smaller scale to compute, average, and report back. Such weak multiscaling dilutes or eliminates nonlinearities and the resulting models misrepresent the observed macroscale behavior. Variabilities in microfunctional parameters not only generate uncertainty within a scale, but also propagate uncertainties between scales, both up and down, resulting in a potentially significant spread in macroscopic properties. Removing degrees of freedom from a dense system during upscaling may result in loss of information that can only be accounted for by introducing suitable random and dissipative forces that render the final mathematical formulation stochastic. What is required is a mathematical foundation for a computational framework of several strongly linked scale models for functional materials, with attendant uncertainty quantification. The mathematically rigorous Mori-Zwanzig formulation appears to be a good candidate for building intermediate reduced order models that can be correlated with intermediate scale (crystal, domain, phase, composite) data and form the basis of models at these scales. Reduced-order methods and multi-rate integration schemes have very different bases, but can also help form these intermediate models. The recent Multiscale-Coarse Graining (MS-CG) method is a new formal variational method that appears capable of rigorously connecting equilibrium ensembles with atomistic and CG models. Hybrid-coupling algorithms have proven useful in computations in large scale applications, such as large linear systems with complex banding and sparsity; similar hybrid-coupling between methods and scales may be useful for upscaling and downscaling models between functional material scales. Insights from materials informatics, multiscale modeling and a robust experimental feedback loop hold promise of unraveling novel properties in functional materials and their underlying physics.

Objective: To discover novel functional materials with unprecedented physical properties through strongly linked multiscale models developed specific to the materials systems, while employing materials informatics and experimental confirmations of these models.

Research Concentration Areas: The research concentration areas include but are not limited to: 1) For any one or more of the systems of novel perovskite (ABO3 type) oxides, novel semiconducting mismatched alloys (e.g. GaN 1-x Asx), 2D free-standing nanomaterials/heterostructures (e.g. transition metal di-chalcogenides etc.), develop a *first-principle rigorous approach,* including techniques of stochastic multiscale variational methods, reduced-order methods, multi-rate time integrators, and stochastic PDEs, that may unify coarse-graining models over several intermediate scales, such as the mathematically rigorous Mori-Zwanzig exact formulation and new coarse-

graining and hybrid coupling algorithms, to predict novel properties; 2) Create the stochastic models that combine multiscale methods across several contiguous scales with uncertainty quantification, and utilizing insights from material informatics; 3) Establish a feedback loop of systematic experiments including processing of samples with different compositions/defects/ microstructures and characterization to confirm and refine multiscale models to predict and achieve unique functional properties.

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

Research Topic Chiefs: Dr. J. Myers, ARO, 919-549-4245, joseph.d.myers8.civ@mail.mil; Dr. C. Varanasi, ARO, 919-549-4325, chakrapani.v.varanasi.civ@mail.mil

ARO FY2014 MURI TOPIC #5

Submit white papers and proposal to Army Research Office

Multistep Catalysis

Background: The Krebs cycle is an exquisite example of a regulated enzyme cascade which biological systems use to precisely control charge and reactant transport to produce energy for the cell. Conversely, man-made systems typically involve a series of conversions with intermediate purification steps to achieve a desired product, with yield losses that compound with each step. The current approach to achieve multi-step reactions in a single reactor is an arbitrary combination of multiple catalysts that is likely to lead to poor yield with unreacted intermediates or byproducts of reactants that have reacted with the incorrect catalysts. Recent breakthroughs in materials synthesis, such as self-assembly and lock-and-key type architectures, offer control of surface arrangement and topology that enable a much more effective approach to achieving multi-step reactions through control of spatial and temporal transport of reactants, electrons, intermediates, and products. For example, it is now possible to design inorganic catalyst systems with 3-dimensional structures that influence mass transport, and perform sequential reactions with high yield. Precise transport of intermediates can be achieved through fluid flow, solid/liquid phase diffusion, or surface migration; however, the interplay between reaction kinetics and nanoscale transport are poorly understood, and modeling such phenomena presents unique challenges. Molecular-scale models typical for catalysis must be complemented by continuum scale models that consider vastly more complex system dynamics and interactions. Controlled synthesis of nanoparticle assemblies, metal-organic frameworks, biomimetic synthetic structures, molecular wires, and supported molecular assemblies with surface and topological control offers new opportunities to design and control mass and charge transport. What is desired is a new approach, combining these structural opportunities with adaptive materials compositions and processes, to provide unique paradigms for exploiting and controlling multistep catalysis with dramatically enhanced efficiency and complexity. These approaches offer extraordinary possibilities for energy production and storage. To achieve such fundamental understanding it will be necessary to bridge the understanding of material design, catalysis, and reaction kinetics at local and continuum scales.

Objective: The objective of this MURI is to enable multi-step/cascade chemical and electrochemical reactions through the rational design of material architectures that control the spatial and temporal pathways of precursors, intermediates, and products. Successful efforts will establish methodologies for modeling, designing, characterizing, and synthesizing new materials and structures for the design and implementation of multi-step catalysis. Efforts that are limited to simple chemical catalysis are not relevant to this topic.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) advanced fabrication and deposition techniques to design three dimensional, solid-state architectures capable of providing spatial and temporal reaction controls, (2) novel methods of controlling mass transport at the molecular scale, (3) models at both atomic and continuum scales to inform the selection and design of materials and structures, to identify the most promising pathways for material preparation, and to distinguish the interplay between reaction kinetics and nanoscale transport (4) surface characterization and spectroscopy techniques with sufficient spatial and time resolution, in addition to sensitivity, to characterize reaction and transport of reactants and

products. This announcement is not soliciting solely enzyme-based solutions although they may be included as a component of a broader approach.

Anticipated Resources: It is anticipated that awards under this topic will be no more than $1.25M per year for 5 years, supporting no more than five funded faculty researchers. Proposed exceptions should be presented during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Robert Mantz, ARO, 919-549-4309, robert.a.mantz.civ@mail.mil; Dr. Dave Stepp, ARO, 919-549-4329, david.m.stepp.civ@mail.mil

ARO FY2014 MURI TOPIC #6

Submit white papers and proposal to Army Research Office

Innovation in Prokaryotic Evolution

Background: Classical Darwinian evolution selects for individuals that are better than others of their species in critical areas associated with reproductive fitness; giraffes are selected for longer necks, cheetahs for faster running, and male bluebirds for bluer feathers. Single celled organisms growing in rich media are selected for their ability to reproduce more quickly. In contrast, organisms that have run out of food can no longer just get better at what they already know how to do; they are forced to innovate new methods to exploit previously untapped resources. In addition, it is known that, in times of scarcity, even unicellular organisms rapidly evolve into complex societies with assorted subpopulations formed with unique and specialized skills. In starving cultures, it is no longer an effective strategy to grow faster. Killing the other organisms with toxins has short-term benefits but results in long-term extinction if you need what the other organisms produce. In short, evolution during lean times requires the group to evolve as a whole, as each individual competes, cooperates and depends on other members of the group. The intent of this MURI is to create a new mathematical model of the multidimensional network of group evolution that accurately describes evolution in groups that are large, isolated, interdependent, and starving.

Objective: The objective of this MURI is to develop a model of evolution in isolated independent cultures of organisms that are starving for months or years. The goal is to characterize, understand, and model change in the genetic, epigenetic, transcriptomic, proteomic, metabolomic, and social networks to create experimentally validated, mathematical rigorous, predictive models that accurately reflect the real complexities of group evolution. The intent is to characterize socioevolution of organisms that are forced to innovate, in long-term (months to years) starving cultures, with a systems biology approach, i.e. fully characterizing the changes in the genome, epigenome, transcriptome, proteome and metabolome in all the different subpopulations of evolving cultures, as well as the interactions between the newly forming subpopulations (the interactome), in order to create a mathematical model of the population network that accurately describes and predicts the evolution and dynamics of group behavior in closed systems over time.

Specific Research Concentrations Areas: Suggested research areas include but are not limited to the following: 1) New mathematical models that accurately describe and predict evolution of constrained populations. 2) Collaborative exploration by geneticists, biochemists, and microbial physiologists to characterize the metabolic and genetic changes in all of the subpopulations of bacteria over time in multiple independent long-term stationary-phase cultures. 3) Mathematical and network analysis of the data from many independent cultures to create a model that describes how large social populations, that both compete and cooperate, successfully evolve. 4) Experimentally determine the validity and limitations of the resulting model across species. Success will be the creation of a mathematical model of evolution that can describe, predict, and understand group evolution and dynamics over time in a closed system, that robustly transcends across species, and that identifies the critical factors that determine whether individuals and groups live or die.

Anticipated Resources: It is anticipated that awards under this topic will not exceed $1.25M per year for 5 years, supporting no more than six funded faculty researchers. Exceptions warranted by specific proposal approaches should be discussed with the topic chiefs.

Research Topic Chiefs: Dr. Micheline Strand, ARO, 919-549-4343, Micheline.k.strand.civ@mail.mil; Dr. John Lavery, 919-549-4253, ARO, john.e.lavery4.civ@army.mil

ARO FY2014 MURI TOPIC #7

Submit white papers and proposal to Army Research Office

Ultracold Molecular Ion Reactions

Background: DoD S&T programs continue to make large investments in the development of molecular ion trap technology for quantum computing and precision metrology. There now exist exciting opportunities to exploit these important technological advances, which include long lifetimes, cooling, exquisite control of the degrees of freedom, and integration with additional *in situ* devices to enable new methods in ion chemistry and photochemistry research. Recent scientific breakthroughs have been achieved in ultra-cold chemistry with neutrals, suggesting that ion chemistry would provide similar opportunities for an emerging new field. In addition, work in quantum information has led to the development of new types of arrayed micro-fabricated ion traps, connected together with a linear density of one trap per 50 micrometers. Ion trap technology adds dramatically novel capabilities to molecular ion research enabling new research opportunities to such areas as materials science, condensed-matter physics, chemistry, and biochemistry. In particular, ion traps offer dramatic improvements in chemical sensing, specifically at the single-ion level of detection. Molecular ion traps have deeper potentials, which offer a unique opportunity for new research by providing long interrogation times compared to neutral trapping methods. Molecular ion trap technology, due to its lithographic construction, is ideal for integrating additional *in situ* devices such as superconductors and quantum dots, providing a host of additional research tools. This new technology offers an increased range of reaction sets that can be explored, especially by generation of different sets of reactants in adjacent traps which can then be allowed to combine in a third trap for study of reaction dynamics; in addition they allow for including molecular ion chemistry and photochemistry, which are both relevant to atmospheric physics, and novel molecular ion reactions of explosives, many which are extremely important to the DoD mission and are poorly understood compared to neutral molecule chemistry. The depth of the molecular ion traps could enable the study of larger single molecules over longer times, an important requirement for studying biological molecular ions, environmentally important species, and specific chemical sensing applications. Trapping and external cooling in molecular ion traps is not species-dependent and therefore generic schemes could be developed for a host of significant species. Finally, these molecular ion traps can be integrated into quantum control experiments to allow coherent control over chemical reactions. Compared with molecular neutrals, trapped molecular ions offer interaction times much longer than what is possible in beam experiments; state preparation and readout is potentially cleaner; and Coulomb interactions with co-trapped atomic ions allow for general species-independent techniques.

Objective: Develop, create and exploit molecular ion traps to: (1) exploit long interrogation time to study molecular ion chemistry; (2) utilize extended interaction times and dipolar interactions in novel quantum control scenarios; (3) improve chemical sensing using single-ion detection; and (4) integrate the traps with various detectors, and (5) determine methods for trapping biological molecules.

Research Concentration Areas: Possibilities include: Developing molecular ion traps to study cold

ion chemistry and photochemistry; study chemistry of molecular ions derived from explosive materials; utilize unique molecular states, ion trap technology, cooling methods and long interaction times to generate new capabilities in quantum control; develop highly sensitive, compact chemical detectors with expanded capabilities and resolution; integrate with other detectors; and develop larger trapping potentials for studying biological molecules.

Anticipated Resources: It is anticipated that awards under this topic will be no more than $1.25M per year for 5 years, supporting no more than seven funded faculty researchers. Proposed exceptions should be presented during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Paul Baker, ARO, 919-549-4202, paul.m.baker4.civ@mail.mil; Dr. James Parker, ARO, 919-549-4293, james.kenneth.parker@us.army.mil

ARO FY2014 MURI TOPIC #8

Submit white papers and proposal to Army Research Office

The Skin-Microbe Interactome

Background: Human-bacterial interactions are the culmination of millions of years of adaptations and co-evolution. Our microbial co-inhabitants outnumber human cells by ten to one and harbor an incredible amount of genetic diversity that directly affects our health and well-being. Interactions with our microbes are required to mature and modulate our immune system and protect us from pathogens. The effectiveness of our first line of defense against infection, the skin, is controlled in part by a dynamic microbiome, yet the mechanisms of these interactions are not well understood. For example, most humans have skin microbial communities that exclude specific pathogens, such as the virulent soft tissue pathogen *Staphylococcus aureus*. Recently, researchers found that *S. epidemidis*, which forms part of the human skin microbiome, can exclude *S. aureus.* However, it is unknown why ~30% of individuals can still be colonized with the pathogen despite the presence of *S. epidermidis*. Skin microbes also cause other effects such as producing volatile compounds that attract biting insects, cause body odor, and likely act as subliminal social cues. Insect attraction varies by individual and the variation is linked primarily to skin microbe-produced volatiles; some individuals can actually repel mosquitoes. Despite the importance of the skin microbiome, very little is known about how microbes on our skin interact with our bodies and with one another.

Until recently, it was impossible to collect the data necessary to conduct fundamental studies on these intricate skin-microbe and microbe-microbe interactions; breakthroughs in DNA sequencing and technical achievements in metagenomic library construction now enable never-before-possible collection of the requisite data. In addition, theoretical ecology is primed to be adapted to multi-dimensional host-ecosystem interactions; key differences between traditional ecological communities and skin microbial communities (in which the "habitat" [the host] is itself a living, co-evolving member of the community, and the interactions are largely cooperative instead of predator-prey) will require fundamental and novel departures from existing theory. Recently developed pairwise metabolic models and genome-based computational tools can now be generalized and linked to these ecological models to produce sophisticated, multiscale biophysical models. These advances, coupled with innovations in metagenomic sequence assembly methods, now make it possible to dissect the interactions among and between microbes and host in the human skin environment. Deciphering these interactions is critical to build a foundation for a wide range of future applications.

Objectives: The objectives of this topic are to discover and characterize the complex host-microbe and microbe-microbe interactions occurring in the skin microbiome, to map the underlying mechanisms of these interactions, to establish and validate a multiscale model of microbiome dynamics that effectively predicts the effects of specific changes, and to use the knowledge gained to identify and validate compositions of skin microbial communities that exhibit optimal properties, such as reduced attraction of insects.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) metagenomics and bioinformatics to characterize the microbiota; (2) microbial ecology and

microbiology to characterize and manipulate community structure and identify metabolic pathways; (3) chemistry and biochemistry to identify volatile compounds and measure changes in composition due to microbiome dynamics; (4) ecological modeling for understanding and modeling complex microbial community-host interactions; and (5) statistics and machine learning for high dimensional compositional data analysis.

Anticipated Resources: It is anticipated that awards under this topic will be no more than $1.25M per year for 5 years, supporting no more than six funded faculty researchers. Proposed exceptions should be presented during the white paper phase of the solicitation.

Research Topic Chiefs: Dr. Wallace Buchholz, ARO, 919-549-4230, wallace.g.buchholz.civ@mail.mil; Dr. Virginia Pasour, ARO virginia.pasour@us.army.mil

AFOSR FY2014 MURI TOPIC #9

Submit white papers and proposal to Air Force Office of Scientific Research

Time-resolved quantum dynamics of complex systems

Background: Attosecond science has rapidly grown over the past decade into one of the most-exciting research frontiers in physics. Born from the convergence of extreme nonlinear optics and femtosecond laser technology, the ability to produce extreme-ultraviolet (XUV) coherent light pulses with durations of a few tens of attoseconds (as = 10^-18 s) has provided an unprecedented set of stroboscopic tools ideal for investigating electronic wavepacket dynamics on the atomic/molecular scale. Proof-of-principle experiments have already resolved ultrafast electronic processes in atoms and molecules at the natural time scale of the electron dynamics. Since the first demonstration of attosecond pulses in 2001, substantial technical progress has been made in both attosecond source development and characterization. Single, isolated attosecond pulses have been realized by exploiting the extreme nonlinear interaction, known as High Harmonic Generation, of carefully engineered intense femtosecond driving laser fields (e.g. using phase-stabilized, few-cycle near-infrared laser systems) with matter and using complex temporal isolation gating techniques (e.g. amplitude gating, polarization gating, double optical gating). Presently, attosecond beamlines in both the US and abroad, have produced isolated pulses with durations as short as 67 as, photon energies of order 100 eV, and pulse energies in the nanojoules. Research to date has primarily been limited to fundamental studies of processes in gas-phase atomic systems and small molecules.

Objective: The objective of this effort is to spur future scientific advances in attosecond science by (1) developing next-generation attosecond light sources and (2) extending the research to complex systems (e.g. solids, nanoparticles, plasmas and large molecules), enabling time-resolved studies of correlated electronic, plasmonic and excitonic processes.

Research Concentration Areas: This topic seeks to address broad research challenges in attosecond science and technology. Areas of interest include, but are not limited to:
(1) experimental techniques (e.g. high power, long wavelength driving lasers, novel high harmonic generation schemes, etc.) aimed at generating high-flux single isolated pulses approaching 10 as, microjoule pulse energies, and photon energies from the soft x-ray regime to 0.5 keV, (2) sub-cycle temporal isolation gating schemes compatible with next-generation attosecond light sources, such as those using long wavelength driving lasers, (3) attosecond pulse characterization techniques consistent with ultrashort, broadband (e.g.10 as) pulses, (4) true attosecond pump-attosecond probe spectroscopy using high-flux, microjoule-level pulses, (5) precise theoretical and computational methods for reliable, nonperturbative treatments of strong-field AMO physics and (6) the extension of attosecond science to complex systems including, but not be limited to, condensed matter, nanoparticles, plasmas, and large molecules.

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

solicitation.

Research Topic Chief: Dr. Riq Parra, AFOSR, 703-696-8571, enrique.parra@afosr.af.mil

AFOSR FY2014 MURI TOPIC #10

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Computational Foundation of Mathematics and Information

Background: Shannon's classical information theory has been a lynchpin of various models of communication process, whose system states and their transitions can be described by deterministic or stochastic finite-state machines. These automata are, however, examples of Turing's computational models. Thus, the mathematics-information nexus was already firmly established in the first half of the 20th century. In the present age of Big Data and information-driven applications, the Shannon-Turing framework needs to be revised to account for not only a multitude of data types but also many advanced algorithms in which computational procedures and mathematical reasoning are intimately integrated. Constructive type theory is central to the construction of data types, relations on types, programming logic, and formalized mathematics, whose constructive framework potentially leads to a new mathematical system with unexpected results that cannot be derived with the current system. In recent years, new variants of constructive type theory have emerged with additional mathematics properties that can be ascribed to the interpretation and computation rules of types. These new versions of type theory also resolve deep, problematic issues in the traditional constructive type theory. In brief, the recently discovered type theories should play a fundamental role in representing and computing information in terms of types, beyond data types, and introducing a new foundation for mathematics. The constructability of mathematical concepts and information content will advance scientific research in artificial intelligence, robotics, human-computer interface, to name a few. Most advanced mathematical concepts and aspects of high-level information are presently not constructive. Hence, they require a great deal of human's involvement to create, specify, and verify before they can be programmed into software/hardware for applications.

Objectives: The goal of this MURI topic is to establish a foundation jointly for mathematics and information based on new type theories. Computation, here and hereafter, subsumes constructive procedures such as calculation, proofs, proof search, and algorithmic verification. Demonstration of the value of the research on challenging problems of DoD's interest that are suitable for concolic evaluation frameworks or proof systems is highly recommended.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) Formulation and construction of expressive types for representing information; (2) Properties of new type theories and their computational implication; (3) Formalization of different areas of mathematics for computation; (4) Relations between the structures of types and those of mathematics; (5) New foundation for constructive mathematics.

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

Research Topic Chiefs:

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AFOSR FY2014 MURI TOPIC #11

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Transport and Utilization of Energy Using Plasmon-induced Processes

Background: Light can interact with some nanostructures by exciting the collective electronic resonances of their conduction electrons, known as surface plasmons. These surface plasmons can efficiently utilize incident optical energy via thermal and non-thermal mechanisms to initiate chemical and physical processes. For example, surface plasmons can be spatially concentrated to create very high local temperatures that can drive chemical reactions. Also, thermal transfer on nanoparticles can create novel situations at nanoscale interfaces as evidenced by the recent observation of the evolution of steam from the optical irradiation of room temperature liquids containing plasmonic nanoparticles. Non-thermally, surface plasmons can decay to create non-Maxwellian distributions of hot electrons that can initiate or catalyze novel surface reactions. Plasmonic nanoparticles can also be used as antennae for solar cells if the absorbed energy is transported efficiently with these systems, and can catalyze processes that can store energy in chemical bonds such as water oxidation and CO_2 reduction. There are many potential ways to use surface plasmons to transport and utilize optical energy to drive unique processes with potential important consequences, however, the fundamental understanding of the driving forces of these nanoscale processes are not well established and limit developments in this field. Thus, a program to study the fundamental driving forces of the processes initiated by surface-plasmon excitation and decay will open many exciting scientific opportunities.

Objective: The object of this effort is to establish a fundamental understanding of the pathways and molecular mechanisms involved in the conversion of optical energy into physical or chemical processes mediated by surface plasmons. We seek to understand the mechanisms by which surface plasmons can initiate or catalyze chemical processes, and use that understanding to improve the design of nanostructures and their interfaces to efficiently utilize incident optical energy.

Research Concentration Areas: Areas of interest include, but are not limited to: (1) Understanding the mechanisms by which hot electrons produced from surface plasmons can catalyze chemical reactions; (2) Exploring novel mechanisms of initiating chemical reactions by surface plasmons supported by quantum mechanical and electromagnetic modeling; (3) Understanding the details of nanoscale heat transfer at illuminated nanoparticle-fluid interfaces that can lead to steam generation or other novel processes at interfaces; (4) Development of structures or architectures for the efficient transfer of energy and charge from plasmon-excited nanoparticles to adsorbates or structures that can utilize this energy.

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

Research Topic Chief: Dr. Michael R. Berman, AFOSR, 703-696-7781, michael.berman@afosr.af.mil

AFOSR FY2014 MURI TOPIC #12

Submit white papers and proposal to Air Force Office of Scientific Research

Design Rules for Biobased and Bioinspired Materials

Background: In nature, the chemistry and structure of complex polymers is controlled at the genetic and biochemical level, leading to materials with unusual and useful properties (e.g., nanocomposites, tough ceramics, strong fibers, optical lenses). Biological systems have developed multiple solutions to similar material problems—for example, abalone, mantis shrimp, and toucans all produce lightweight and strong biomaterials from variable 3D structures. Synthetic biology promises to recreate or even redesign these systems and their properties from the bottom up, mixing and matching standard biological parts in the same way one designs a new car. This approach, however, has proved daunting, in part due to compositional complexity and multivariate solutions arising from constraints specific to a particular species. What's needed is a principled way of reducing the complexity of the problem. This program proposes a more intermediate goal: the ability to predictably design biomaterial functions and properties, rather than whole systems, utilizing bioinformatics and computational theory to explore the basis of multiple structure/function relationships. Synthetic biology is focused on the rational engineering of biological systems, allowing us to exploit evolution's advances while creating new materials and systems that do not yet exist. A set of design rules to impart specific material properties and functions in biobased and bioinspired materials would greatly inspire industrial applications even before the aim of standardized biological parts could be realized.

Objective: The objective of this MURI is to develop the scientific foundations needed to predictably design desired functions or properties in bio-based or bio-inspired materials. It will result in a quantitative understanding of biological materials to an extent that one is able to predict material features as well as design and modify their behavior. The ultimate goal is a set of design rules for a subset of material properties that provides a proof of concept, as well as a process that may inform the broader goal of the creation of standardized biological parts.

Research Concentration Areas: Suggested research concentration areas include but are not limited to: 1) bioinformatics that relies on an evolutionary or systems biology approach to discover model biomaterial systems that can elucidate the basis and options for a particular biomaterial property, but also the basis for its absence and the trade-offs involved, 2) chemists, material scientists, and/or engineers who can fully examine the relationship between genetic information, physical structure, and material properties, 3) mathematical or computational models/theory that brings a predictive capability to biobased and bioinspired material design. The specific material properties examined in this study are less important than the use of model biological materials with enough diversity to provide a basis for the development of design rules. Note that this project should not focus on bioprospecting, though new organisms may be sought to fill gaps identified through bioinformatics.

Anticipated Resources: It is anticipated that awards under this topic will be no more than $1.5M 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 Chiefs: Dr. Hugh De Long, AFOSR/RTD, 703-696-7722, hugh.delong@afosr.af.mil; Lt Col Jennifer Gresham, PhD, AFOSR/RTD, jennifer.gresham@afosr.af.mil

AFOSR FY2014 MURI TOPIC #13

Submit white papers and proposal to Air Force Office of Scientific Research

Control of Coherent Structures in Plasmas for Reconfigurable Metamaterial-Based Devices

Background: Coherent structures, namely arrangements that are spatially and/or temporally ordered variations in the plasma properties, are emergent physics resulting from the long-range Coulomb forces inherent in charged particles. A variety of plasma devices, such as high-power microwave sources, rely on these structures for their performance. However, many devices, such as fusion tokomaks and electric thrusters, are not designed to use these variations, and the coherent structures can lead to reduced performance, and even damage to the device. This damage can occur in a number of ways: Coherent structures can develop resonant absorption with applied fields in an electro-magnetic device; current filamentation events and streamers can be found in power switches; ionization spokes can be found in plasma thrusters; all of which lead to energy transport sufficient to damage the surround material structure. The control and possible mitigation of these aspects of coherent structures is critical in controlling particle and energy transport and may thus increase the lifetime and the efficiency of a variety of plasma phenomena. Furthermore, forming and controlling coherent structures in plasmas can also be technology-enabling: Arrays of coherent structures can behave as plasma photonic crystals (PCs) or plasma metamaterials that, when interacting with electromagnetic (EM) waves, have dispersive properties that are not generally found in nature, and can exhibit EM band gaps near plasma resonances and cut-offs which can spectrally filter and guide EM waves. The use of plasma coherent structures with high spatial and temporal fidelity affords a means of PC construction that is reconfigurable over short timescales. These same classes of plasma structures can also be used to perform analog computing in hostile environments, including space-based radiation fields, and thus provide real-time sensing/computing capability. Coherent structures form naturally from random fluctuations, and thus control of both the spatial/temporal features of the plasma and its interaction with the resulting applied and self-electric/magnetic fields provide the energy for the evolution of these structures. This self-organization is a key feature in the development of plasma PC devices. Throughout the entire range of scales and frequencies, interesting EM wave interactions can be obtained by combining plasmas with other materials (e.g., metals) in ways that form metamaterials as well as provide control of the electromagnetic energy flow.

Objective: The objective is to expand the scientific base for understanding the formation, control, and mitigation of coherent structures in plasmas. A further objective is to form and control through external means the inherent self-organization of long-range ordered structures over a range of scales. The control of these structures offers the means to form plasma-based metamaterials that can interact with wavelengths that span the microwave to THz range of the EM spectrum.

Research Concentration Areas:_ (1) To develop plasma simulations that can describe the formation of coherent structures from initial plasma states and their response to external stimuli. (2) To perform experiments that generate coherent structures and to apply diagnostics methods to characterize them. (3) To demonstrate control that leads to the production of plasma-based photonic crystals. (4) To investigate the interaction of electromagnetic waves with the generated

plasma photonic crystals and to simulate this linear and non-linear interaction.

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

Research Topic Chiefs: Dr. Mitat A. Birkan, AFOSR, 703-696-7234, mitat.birkan@afosr.af.mil, Dr. Ali Sayir, AFOSR, ali.sayir@afosr.af.mil

AFOSR FY2014 MURI TOPIC #14

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Multifunctional Quantum Transduction of Photons, Electrons and Phonons

Background: The integration of electron spins into photonic structures has enabled coherent exchange of information between photons and spins. Combinations of optically and mechanically-active structures with strong overlapping 3D confinement of these fields have enabled strong coupling between photons and phonons, yielding significant advances in the performance of optomechanical systems. Primitive 1D and 2D phonon circuits are beginning to be developed. Experiments have demonstrated sideband cooling of the mechanical degree of freedom close to the quantum ground state, and efforts are underway to demonstrate optomechanical quantum control of the mechanical degree of freedom. Electrically-controlled microwave frequency mechanical resonators have been developed with very strong electromechanical coupling. Complete quantum control of one mechanical degree of freedom has been achieved by coupling these devices to superconductor-based qubits, primarily enabled by the strong coupling achieved using piezoelectric materials.

Objective: Develop a quantum technology that expands the capabilities afforded by optomechanical devices by adding active control of the mechanical degrees of freedom via electronic signals in both the classical and quantum regimes. Develop coherent electronic control of both photonic and phononic quanta using electrically-based quantum circuits such as superconducting qubits, or optical or phononic control of synthetic or naturally-occurring atomic defect spin states. Provide multi-field quantum transduction linking electronics, spintronics, mechanics and photonics, and demonstrate quantum control of phonons, enabling photon-like manipulation of this degree of freedom. This quantum transducer should yield (1) high-bandwidth transmission and reception of optically-encoded, quantum-encrypted information, providing secure high-bandwidth communication; (2) the development of coherent coupling between hybrid quantum systems, and (3) new integrated means for quantum information storage and processing.

Research Concentration Areas: Photonic and optomechanical structures have been largely based on Si and SiN. Other materials should be considered, e.g., SiC and AlN are now available as high-quality thin films with desirable optical properties, tunable electronic spin, and provide strong piezoelectric response. Properly harnessed, the piezoelectric response enables strong coupling of electrical signals to mechanical motion at microwave frequencies, affording a new mode for high-speed information transfer between photons and quantum-controlled phonons. A focused effort should explore the capabilities of such “3-field” systems. This will require materials processing; quantum structures; coupling modalities; theory, and simulation tools incorporating all degrees of freedom. Strong electro-opto-mechanical coupling, with quantum control over electronic, spintronic, photonic and phononic degrees of freedom, should be achievable. Very high bandwidths for quantum-entangled photonic states may be achieved using such devices; these also should provide new transduction mechanisms for coupling hybrid quantum systems.

Anticipated Resources: It is anticipated that awards will be no more than $1.5M per year for 5 years, supporting no more than 6 funded faculty researchers. Exceptions warranted by specific

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

Research Topic Chiefs: Dr. Harold Weinstock, AFOSR, 703-696-8572, harold.weinstock@afosr.af.mil; Dr. Tatjana Curcic, AFOSR, 703-696-6204, Tatjana.curcic@afosr.af.mil

AFOSR FY2014 MURI TOPIC #15

Submit white papers and proposals to Air Force Office of Scientific Research

Control of Light Propagation through Metasurfaces

Background: Metamaterials (MMs) are rationally designed artificial materials with versatile properties that can be tailored to fit almost any practical need and thus go beyond what can be obtained with "natural" materials. The proposed metasurfaces are optical MMs with a reduced dimensionality. In contrast to conventional 3D MM designs that often rely on resonance responses and suffer from high loss and challenging fabrication, subwavelength-thick metasurfaces can offer extraordinary properties combined with low-loss, large bandwidth performance as well as fabrication and integration advantages. Moreover, similar to surface science research that in the past revolutionized physics and revealed new phenomena unattainable with 3D systems, moving from bulk MMs to metasurfaces could unlock new physical phenomena and pave the way to truly novel applications.
In contrast to the first optical MMs that were only one unit cell thick due to fabrication limitations. One seeks entirely new approaches for designing 2D metasurfaces with unique optical properties. Of interest is developing new methods of designing and investigating effective optical properties of metasurfaces that have been shown to deviate from classical reflection and refraction laws. This direction would allow one to realize various metasurfaces for "flat photonics" that provide extraordinary control of the characteristics of light, including its frequency, phase, momentum, angular momentum, and polarization. The intent is to develop metasurfaces that direct, route and control the flow of light at both the nano- and macroscopic scales and offer new, exciting functionalities.
One example of such unusual properties is the recently discovered generalized Snell's law that allows unprecedented control over reflection and refraction of light at an interface by using an array of optical nanoantennas. The proposed metasurfaces present an entirely new perspective on light manipulation and create a new paradigm for the science of light. New ultra-thin devices based on metasurfaces could enable important applications ranging from efficient light modulation, pulse shaping, beam steering, imaging and sensing with the nanometer-scale precision to novel quantum-optics and quantum-computing systems.

Objective: Explore an entirely new class of 2D and quasi-2D metamaterials – metasurfaces – with the goals of overcoming the current limitations in the emerging metamaterial technology, unlocking new physical phenomena, and exploring truly novel applications of the proposed metasurfaces in optical, optoelectronic, sensing, imaging, nanofabrication, and quantum information technologies.

Research Concentration Areas: Areas of interest include, but are not limited to the following: (1) exploring the new physics and applications resulting from the recently discovered generalized Snell's law; (2) studying novel applications of such nanoantenna-array metasurfaces, including ultra-fast and ultra-thin spatial light modulators, chiral "flat photonics" structures, ultra-thin lenses with extraordinary focusing strength, and dynamically controlled pulse shaping and beam steering devices; (3) modeling, simulating and investigating experimentally the spectral and

polarization converting properties of arrays of identical antennas and of antenna arrays with a phase gradient; (4) studying the so called hyperbolic metasurfaces (HMS) and explore their properties and applications; (5) exploring the possibility of using novel, low-loss, plasmonic and related materials as material building blocks for metasurfaces; and (6) studying the scaling, cost-ineffective fabrication, and sub-system implementation of such surfaces.
Resources: Awards under this topic would be aimed at Multidisciplinary Teams at the $1.00 M to $1.3 M/year level for five years, supporting no more than 7 funded faculty researchers.

Research Topic Chief: Gernot S. Pomrenke, AFOSR, 703-696-8426, gernot.pomrenke@afosr.af.mil

AFOSRFY2014 MURI TOPIC
#16

Submit white papers and proposals to Air Force Office of Scientific Research

Goal-Driven, Multi-Source Algorithms for Complex Resilient Multi-Physics Systems

Background: Analysis, design, risk assessment and decision making based on performance of physics-based complex systems require accurate prediction of the response at the component and system level. While these high-level activities have large cost impact, predictions of behavior of these systems made with assorted existing analysis methods/algorithms are often not trusted. A major contributor to this lack of trust is the absence of a credible mathematical framework by which physics based models can be combined within and across disciplines, and supplemented with other sources of information such as experiments and expert opinions at a certifiable level. A further challenge is applying models beyond their historical comfort zones, adapting them to new decision goals, new configurations and new regimes of behavior and operating environment. It is unclear how changing the accuracy of one model enables a more informed decision when models are linked in new ways, for different configurations, and for diverse physical behaviors. What is needed is a set of new mathematical algorithms that can adaptively orchestrate the selection/arrangement of different sources of information/data/models needed to predict the multi-physics/multidisciplinary response of the system for a specified decision in an allotted time.

Objectives: To develop a mathematically rigorous framework for adaptive selection of different sources of information from data/models for accurate prediction of the response of a system. These algorithms should mathematize the dependence of goals on the disciplines modeled and the available modeling sources to create a “multi-source decision function” accounting for evaluation accuracy, time, cost, parametric representations of models, physical conditions, and configuration geometry and uncertainty in all these aspects. The algorithms should predict system behaviors critical to decisions being made by a variety of evaluators, including analysts, designers, or potentially other multi-physics algorithms. The algorithms should quantitatively assess: which disciplines/physics to couple (from all possible combinations); how tightly to couple the disciplines/physics; which theoretical model sources to select (from all available) from a given domain to predict the multi-physics response of the system for goal driven decisions. Finally, new algorithms need to be demonstrated on a specific system of interest.

Research Concentration Areas: (1) Developing a mathematically rigorous information-theoretic framework for assessing variable-fidelity information across multiple scales and checking for compatibility of coupled multi-physics models with different fidelity; (2) Developing efficient and accurate algorithms for utilizing high-fidelity methods(e.g., PDE solvers) to construct low-fidelity models(e.g., reduced-order models) while maintaining accurate representation of underlying physics; conversely, utilizing low-fidelity models to determine when high-fidelity is needed, what is the underlying functional dependence of "fidelity" to variables contained in the model; (3) Designing with variable-fidelity possibly uncertain

numerical simulations, where requirements to choose level of fidelity are needed to account for dynamic system modeling; (4) Inclusion of data from tests and system operation as feedback into a robust design process featuring stable computations.

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

Research Topic Chiefs:

Dr. Fariba Fahroo, AFOSR, 703-696-8429, fariba.fahroo@afosr.af.mil;
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AFOSR FY2014 MURI TOPIC
#17

Submit white papers and proposals to Air Force Office of Scientific Research

SECURITY THEORY OF NANO-SCALE DEVICES

Background: Nano-scale devices, devices that take advantage of physical properties of materials that dominate at the nano-scale and beyond (e.g. quantum tunneling), will be pervasive in the future. Research into these devices often focuses on the fundamentals of device operations, manufacturing and reliability, but rarely on their security properties. Whether they take the form of ever shrinking CMOS devices, next generation memristors, resistive and phase change memories or nano-sensors, the security properties of such devices have not been thoroughly studied. Researchers and practitioners have developed different techniques to exploit current generation hardware devices using focused ion beams and laser trimming for reverse engineering, differential power analysis and fault injections for side-channel attacks and selective wearing for denial of service attacks. Researchers have also presented a number of security primitives such as physical unclonable functions (PUFs) that take advantage of manufacturing variability, logic obfuscation designs to limit the extent of reverse engineering and Trojan insertion, and power flattening circuitry to defeat side-channel analysis. However, these attacks and defenses often abstract away many of the lower level details necessary to fully explain the effectiveness of the proposed techniques. As a result, while current results on macro-devices show promise (e.g., CMOS based PUFs are unique), it is difficult if not impossible to infer whether current techniques, both attack and defense, are still viable for upcoming nano-devices and whether there are new classes of attacks and defenses made possible by nano-devices. There are a number of fundamental security related questions for nano-devices: Do smaller feature sizes naturally make reverse engineering more difficult; does the scale make the circuitry more susceptible to fault injection attacks; does the destructive nature of filament growth and breakage in memristors lead to easier denial of service attacks; how does self-assembly of nano-devices affect manufacturing variability and transitively the viability of PUFs; and what choice of materials will lead to the most reliable and yet variable nano-devices?

Objectives: The objective of this MURI is to develop the theory to predict the security properties and vulnerabilities of the next generation of Nano-scale devices.

Research Concentration Areas: Suggested research areas include, but are not limited to the following: 1) Investigate the relationships between nano manufacturing artifacts and security primitives such as process variability; 2) Use hardware attack models to develop a theory or theories that relate physical properties of devices to robustness of micro and nano devices against these attacks 3) Establish theories or fundamental principles that relate physical properties of devices to anti-tamper, reverse engineering, PUF and Random Number Generation properties; 4) Reveal new classes of attacks that are unique for nano-devices; 5) Invent metrics for evaluating and comparing the security properties of micro and nano technologies based on vulnerability theories.

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

Research Topic Chief: Dr. Robert Herklotz, AFOSR, 703-696-6565, robert.herklotz@afosr.af.mil

ONR FY2014 MURI TOPIC #18

Submit white papers and proposals to Office of Naval Research

Understanding Energy Harvesting Mechanisms in Polymer-Based Photovoltaics

Background: Just a decade ago, the power conversion efficiencies of champion laboratory organic photovoltaic cells were about 2%. Champion cell efficiencies are now above 10%. The rapid advancement gives hope that very low cost, light weight and flexible solar cells will one day reach the market place. The advances that have brought the community from 2% to 10% power conversion efficiency have come mostly from (1) the design and synthesis of improved donor materials with better frontier orbital energy level offsets with fullerene acceptors and broader absorption, (2) improved bulk heterojunction morphologies based on casting procedures with mixed solvents and additives to optimize the phase separated domain sizes in the bulk heterojunction, and (3) improved electrode/organic interface treatments or layers.

This performance enhancement was achieved despite increased confusion over exactly how energy is harvested. Conventional wisdom is that a photon is absorbed resulting in the formation of an exciton. The exciton diffuses until it reaches a heterojunction. The energy level offsets of the junction lead to a splitting of the exciton into separate charges, and the separate charges migrate to respective electrodes under the field imposed by the electrode work functions. What is actually happening from photon absorption through charge separation is not fully known and differs depending on: specific donor and acceptor materials; the morphology of the bulk heterojunction; mobility of the separated charges; order/disorder in within phase domains and at the heterojunction interface; and so on. In some cells, the majority of the electrons harvested appear to come from a fast process not consistent with exciton diffusion to a junction while in others there are signatures of multiple processes. Which processes are desirable? What donor and acceptor energetics allow them to occur? Which geometrical/morphological properties encourage desired behavior?

The goal of this MURI is to design materials systems for optimal performance along desired energy harvesting pathways based on self assembled materials with appropriate intra- and inter-molecular electronics in the bulk and at the heterojunction interface. The challenge is huge because organic devices are not highly ordered but they also have localized and delocalized electronic properties that are dependent on packing. Molecular dynamics should be able to model phase separation and molecular packing in a bulk heterojunction. DFT has given clues to geometric dependence of intermolecular electronic processes. Ultrafast spectroscopies carried out in the solid state are providing clues to details of these processes.

Objective: This objective of this MURI is to provide a better understanding of the energy harvesting process in polymeric/organic photovoltaics on a fundamental level through multiscale computation, through spectroscopic investigation of model systems, solid state systems and bulk heterojunction systems, and with full characterization (morphology, chemical, electronic). New materials should be developed based on theory to encourage charge separation pathways, considering interfacial packing, bulk molecular packing, and domain morphology.

Research Concentration Areas: A balanced, interdisciplinary program consisting of (1) Theory

and modeling; (2) Synthesis of model and OPV materials; (3) sample and device fabrication and electronic characterization; (4) spectroscopic and morphological characterization.

Research Topic Chiefs:

Paul Armistead, ONR 332 Naval Materials,(703) 696-4315, paul.armistead@navy.mil
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ONR FY2014 MURI TOPIC #19

Submit white papers and proposals to Office of Naval Research

Role of Bidirectional Computation in Visual Scene Analysis

Background: A long standing goal in visual science is creation of computational systems that achieve accurate object recognition within complex natural scenes. Natural scenes pose severe challenges: target objects are often partially occluded; object backgrounds contain substantial clutter; the number of object types can be very large, and; objects can appear at any of a very large number of aspect angles, scales, locations, and levels of ambient illumination (the "invariance" problem). Although considerable investment has been made in the field over the past 30 years, computational vision systems do not perform well when processing rich natural scenes: recent evaluations by a Federal funding agency show that the best available computational vision systems recognize target objects in natural scenes with only about 60% accuracy. In contrast, biological vision performs extremely well under these conditions. This sharp performance disparity reflects a key gap in our understanding of the basic mechanisms of biological vision.

The present MURI aims to close this gap by fostering a deeper understanding of and exploiting several recent advances in our knowledge of visual neurocomputation that are not adequately addressed in extant models. First, almost all current neurocomputational models of object recognition are based on theory and data that exclusively emphasize the role of bottom-up, feedforward projections across the visual system. However, it is well known that neural connections in biological vision are bidirectional, with back projections as plentiful as forward projections. The significance of these back projections is revealed by recent evidence that objects embedded in cluttered fields are not perceived unless their neural representations undergo bidirectional patterns of activation extending between primary visual cortex and the highest levels of processing, in the inferotemporal cortex and beyond. One possible hypothesis is that this interplay of bottom-up and top-down projections supports a powerful form of bidirectional constraint satisfaction in which partial activation of the lower level feature detectors linked to object classes constrain activation of experience-dependent higher level representations, which in turn feed back to constrain (reinforce) lower-level feature detectors that cohere with them. While the general notion of mutual constraint satisfaction is broadly recognized, no systematic effort has been undertaken to understand the specific nature of the underlying dynamics. What is the content of the information back projected? How is this conditioned by the particular image features obscured or absent in the image? Are back projections purely an attentive mechanism, or do they also play a role in pre-attentive processing? Second, little effort has been made to develop neurocomputational models that simultaneously capture within a unified theoretical framework the mechanisms of object recognition and figure-ground organization (FGO)—the determination of border ownership, and the segmentation of objects and background. Because many of the challenges of object recognition in natural scenes critically involve the segregation of figure and ground, theoretical unification of the underlying mechanisms will prove of great computational value. Unification is further motivated by recent evidence that FGO, just as object recognition, is strongly modulated by top-down influences within both striate and extrastriate regions of visual cortex. How do these influences interact, and at what levels, to achieve effective

FGO? Mechanistically, what are the roles of context recognition (gisting) and context-dependent memory retrieval in both object recognition and FGO? The creation of powerful, neurobiologically plausible computational models that capture the interplay of top-down and bottom-up interactions in object recognition and figure-ground organization in biological vision now appears feasible. However this will require a broad program of multidisciplinary research integrating neurobiology, cognitive neuroscience, non-linear dynamics, and formal neurocomputational modeling.

Objective: A bidirectional neurocomputational model of biological vision that unifies the mechanisms of object recognition and FGO and demonstrates the capacity to recognize objects appearing in complex natural scenes with a level of robustness significantly exceeding that of current models.

Research Concentration Areas: Suggested research areas include but are not restricted to: (1) Developing a deeper neurobiological understanding of the functionality and specific mechanisms underlying the ubiquitous interplay of bidirectional projections critical to object recognition and FGO; (2) Explicating and computationally modeling the neural processes enabling biological vision to exploit the full range of cues available for FGO; (3) Implementing computational algorithms that capture the functionality and robustness of the learning mechanisms by which FGO is achieved in biological vision; and (4) Understanding, and implementing the mechanisms by which top-down projections from non-visual brain regions (e.g., pre-frontal regions representing context-based expectations derived from prior experience) shape processing across the visual system.

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 chiefs during the white paper phase of the solicitation.

Research Topic Chiefs:

Dr. Harold Hawkins, ONR 341 703.696.4323; harold.hawkins@navy.mil;
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ONR FY2014 MURI TOPI #20

Submit white papers and proposals to Office of Naval Research

Exploring the Atomic and Electronic Structure of Materials to Predict Functional Material Properties

Background: Pervasively across rapidly advancing DOD technologies, material property advancements are needed to meet increasingly stringent multi-functional performance characteristics and environments. New materials with tailored bulk and surface material properties (e.g. transport properties, creep, oxidation resistance, conduction etc.) are needed. There are large differences between the macro level elemental and compound surface layer properties, the causes of which are not understood. These objectives can be approached either through increased fundamental understanding of atomic-to-meso-scale interactions of co-dependent structural, thermal, electrical, and chemical properties on macro-scale surface activity and mechanical response and by experimental development of novel physical/chemical structures. Recent advances in atomic-scale material characterization tools have led to accurate measurements of electronic structure capable of establishing the bonding electron distribution and matching theoretical calculations with experimental results. Once the electronic distribution and energy hyper surface is known, the development and prediction of tailored material properties and responses, including surface energies, crystal micro-structures, defect energies, dislocations, atomic and molecular binding energies that govern transport/diffusion, surface phenomena, and control of thermo-chemical-mechanical reactions becomes possible. Once atom positions are established, equations and theories of functional properties relationships can be created and developed. This can lead to exploring and creating new materials with selectable desired properties at the atomic scale. Calculation of the energy hyper surface is extremely challenging where approaches have used quantum chemistry, solid state physics, and statistical mechanics. Consideration for defects, dislocations, and minor chemical impurities in materials need to be addressed. Grain boundaries and inclusions, which serve as sinks for impurity segregation during materials processes are key sites for combined mechanical, thermal and electrochemical activity in materials.

Objective: Create the multi-scale science that links the atomic structure and bonding energies to critical materials properties, such as chemical stability, environmental cracking, thermal and electrical conduction, and mechanical strength.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) Quantum mechanical modeling and computations to explore lowest atomic and electron energy states that will lead to basic principles for creating new materials, (2) create and validate hierarchical thermo-chemical/mechanical property models that predict bulk and bulk to surface layer material responses (as a function of environment, temperature, loading, defects, etc.) that relate theoretical calculations and simulations with materials processing, (3) correlate microstructure and grain size features with bonding electron distributions, (4) explore composition and hierarchical stability as function of temperature, stress and environment, (5) correlate through modeling and experiment disordered and ordered structures with electron distribution, (6)

establish 2D, 3D, and 4D characterization schemes for validating the theoretical calculations and process simulations, and (7) link atomic-scale predictions to surface chemistry kinetics and meso-scale structural properties for both homogenous and heterogeneous bulk surfaces.

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 6-7 funded faculty researchers.

Research Topic Chiefs: Dr. David A. Shifler, ONR 332, 703-696-0285, david.shifler@navy.mil
Mr. Bill Nickerson, ONR 351, 703-696-8485, william.nickerson@navy.mil
Mr. Gil Graff, ONR 351, 703-588-0703, gil.graff@navy.mil

ONR FY2014 MURI TOPIC #21

Submit white papers and proposals to Office of Naval Research

Optical Computing

Background: The field of Optical Computing, broadly defined as use of optical and optoelectronic technologies in information processing, has been an active area of research with a rich history. Optical computing systems are built upon a mapping of the physics of linear and nonlinear interactions between light and matter to achieve useful computational primitives. For example, a convex lens combined with free space propagation performs complex 2D Fourier Transform and cascade of optical transmittance functions result in a product of these functions. Recently hybrid methods that integrate analog/digital electronic circuits and optics have been investigated for high bandwidth signal processing. This area of research has been motivated by high speed optoelectronic devices (lasers, detectors), massive parallelism intrinsic in optical systems and the ability to achieve non-interfering interconnects with arbitrary topology.

Recent advances in photonics technology have lead to new materials with enhanced and controllable nonlinear response. New developments in semiconductor quantum dots and nanowires, optical metamaterials, photonic crystals, plasmonics and microresonators have provided ways to spatially localize both photons and electrons. Inhomogeneous composite material structures including metal nanoparticles and semiconductor quantum dots embedded in linear or nonlinear polymer matrix make it possible to synthesize materials with customized optical response. These technologies are currently being explored for novel chemical-biological sensors as well as devices for chip-scale optical interconnect.

This MURI will generate new concepts for optical computing and provide critical knowledge and understanding of the information processing implications of advances in the photonic materials and device science and technology. It will lead to innovative ways of implementing standard computational primitives (e.g. multiply, add, switch, delay, store, convolve) with higher performance at lower power. A deeper and functionally-oriented understanding of next generation photonic materials and devices will lead to direct realization of new and more powerful computing primitives. Another research direction will study ways of mapping mathematical description of complex nonlinear optical dynamical systems into realizable computational hardware. Taken together, new knowledge created under this MURI will enable “analog photonic hardware accelerators” to support a wide class of high value real time processing threads that occur in weapon systems and electronic warfare. It will also lead to novel approaches to efficient modeling and simulations of complex, nonlinear dynamical systems.

Objective: The objective of this MURI is to develop new knowledge and create a new paradigm for solving challenging non-linear computational problems in signal/image processing (e.g. image compression) communications (e.g. Viterbi decoding), pattern recognition and simulations of complex nonlinear dynamical systems by exploiting recent advances in photonic materials (e.g. metamaterials, quantum dots, plasmonics) and devices (e.g. microresonators, photonic crystal circuits).

Research Concentration Areas: Suggested concentration areas include but are not limited to: (1) Developing a strategy and envisioning computational primitives that are realized in a variety of nanophotonic materials and devices (2D guided wave as well as 3D free space); (2) Exploring and creating innovative approaches that integrate these primitives into systems that can be packaged and reprogrammed to implement a wide variety relevant algorithms; (3) Investigating the applicability of inverse techniques to design photonic realizations of new, powerful, and widely applicable computational primitives such as nonlinear differential operators; (4) Modeling and simulation of photonic computing circuits/modules that support their implementation and integration; (5) Exploring the applicability of nonlinear optical dynamical systems as a platform for

physics-based computational systems.

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

Research Topic Chiefs: Dr. Ravindra Athale, ONR, 703-588-1916, Ravindra.Athale@navy.mil; Dr. Carey Schwartz, ONR, 703-696-7824, Carey.Schwartz@navy.mil

ONR FY2014 MURI TOPIC #22

Submit white papers and proposals to Office of Naval Research

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.

Research Topic Chief: Dr. Charles W. Clark, ONR, 703-696-5267, clarkc@onr.navy.mil

ONR FY2014 MURI TOPIC #23

Submit white papers and proposals to Office of Naval Research

Air-Sea Interaction and RF Propagation in Maritime Atmospheric Boundary Layers

Background: Physical processes within the air-sea interface occur on scales from centimeters to kilometers and involve nonlinear multi-scale interaction between turbulence, upwelling, surface and internal waves, and entrainment as well as organized structures in the presence of shear and buoyancy such as organized linear eddies and Langmuir cells. While the bulk characteristics of this exchange based on the statistics of turbulence is generally sufficient for numerical weather and ocean prediction (NWP) and ray-trace based prediction of electromagnetic propagation, a clear and explicit understanding of the complex physics and resulting instantaneous refractive index turbulence field remains a formidable scientific challenge, particularly in the presence of complex mesoscale ocean and atmospheric variability. This variability has largely been ignored and assumed to be fully turbulent for the purposes of down-gradient mass and energy transfer; however, newer Defense applications are hampered by the breakdown of the assumptions of isotropy and homogeneity used in similarity theory suitable for low resolution NWP applications developed over the last 50 years.

Understanding and prediction of high frequency electromagnetic/electro-optical (EM/EO) propagation in maritime environments is important for the DoD in order to predict sensor and communications performance and shipboard signatures for counter-detection. Physics-based models of propagation through a similarity-based and therefore partially idealized marine atmospheric boundary layer (MABL) have been sufficient for basic open-ocean prediction at VHF/UHF frequencies; however, at SHF/EHF bands newer emitters and communication networks have shown that bulk environmental parameters do not properly characterize observed effects in the near surface region. The conceptual model of the MABL as a wave-guide has less fidelity at higher frequencies where ocean surface roughness, variability in the inversion height and strength at the upper boundary, and along-path variability in the humidity and temperature fields have much more noticeable effects. The high resolution observations of state variables over large spatial areas required to properly and definitively characterize the maritime surface environment on these scales are not feasible in a dynamic and evolving environment, particularly in the littoral regions of highest interest and Monin–Obukhov similarity theory is not robust enough to reliably fill-in the measurement gaps from routinely observable conditions.

Therefore, approaches are sought to develop a new compact theory of turbulent fluid dynamics at the air-ocean interface that allows for efficient representation of the complex dynamics associated with phase-resolved surface gravity waves at the lower bound (sea and swell) as well as cloud-topped upper boundary layers, that can diagnose and predict the structure and evolution of the MABL at higher spatial and temporal resolutions of order 1 kilometer and 30 minutes without resorting to Direct Numerical Simulation. This model should be able to produce a consistent basic state from initial observed bulk conditions, permit a prediction that matches field-based direct observations of instantaneous refractive index turbulence and state variable gradients, and be suitable for the eventual construction of an inverse model or similar approach that could be used to deduce MABL state variable parameters from observed variability in received electromagnetic

signals.

Objective: To exploit new measurements, improved sampling, and increased capability in coupled numerical modeling to efficiently characterize the multiscale interactions within the maritime boundary layer towards improved diagnosis and prediction of high frequency propagation.

Research Concentration Areas: Within the framework described above, specific areas include theoretical/computational geophysical fluid dynamics, laboratory measurements of relevant phenomena, and simultaneous high resolution field measurements of marine boundary layer parameters and RF fields.

Anticipated Resources: It is anticipated 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 funded faculty. Exceptions warranted by specific proposal approaches should be discussed with the topic chief during the white paper phase of the solicitation

Research Topic Chief: Dr. Daniel P. Eleuterio ,, ONR 322, (703) 696 4303; daniel.eleuterio@navy.mil; Dr. Steve Russell, ONR (331), (703) 696) 4714 , steven.j.russell@navy.mil

ONR FY2014 MURI TOPIC #24

Submit white papers and proposals to Office of Naval Research

Hydrodynamics of Non-traditional Propulsion

Background: We are just beginning to understand the fundamental physical origins of highly efficient thrust that can be generated by nontraditional means (the swimming efficiency of some whales, dolphins and rays has been determined from hydromechanical models and kinematic data to be up to 90%). Production and control of vortices is known to be the principal mechanism for propulsion of flukes, fins and pitching panels. Flexibility across the chord of a foil has been shown to increase leading edge suction which has been shown to increase propulsive efficiency. Animals are hypothesized to control flow passively and actively, thereby enhancing efficiency and thrust and reducing drag. Passive flow control arises from morphological and structural features of the animal, while active flow control results from the movements of the animal's body and its appendages to modify the wake and control hydrodynamic forces during propulsion and maneuvering to optimize performance. The relationship between the structure of the wake and vortices from a pitching panel and efficiency and thrust generation has been described; this creates the possibility of optimization of propulsor performance via manipulation of the wake structure. The muscle/cartilage structure of the manta ray fin has been determined in detail via CT scan, and then modeled with a 3D panel code – this will provide a basis for future understanding of effects of propulsor morphometrics and flexibility on efficiency of nontraditional propulsion.

Rapid progress in experimental and computational techniques has created a plethora of new tools that can be applied to the outstanding research issues in the field of high-efficiency underwater propulsion. Time-resolved, 3D information on wake structure produced by propulsive surfaces can be obtained with the advent of tomographic and holographic PIV approaches. Underwater stereo-electro-optic and LIDAR offer the possibility of obtaining 3D, time resolved data on the morphometrics of the propulsive surface. Advances in artificial muscle technology, tensegrity structures and control enable actuation of engineered propulsor surfaces as well as active flow control. Progress in computational power and speed are making advanced computational fluid dynamics (CFD) methods such as RANS and LES codes, including incorporation of hydroelastic effects, more readily available and feasible in terms of computational time and cost. Of interest for this MURI is the use of techniques such as these to advance the fundamental understanding of the efficiency of nontraditional underwater propulsors.

Objective: A fundamental understanding of the hydrodynamics of nontraditional propulsion and in particular, the physical origins of high efficiency propulsion by nontraditional means. An understanding of the relationship of wake structure, propulsor kinematics, morphometrics, fluid-structure interactions, and passive/active flow control over the propulsor surfaces, to efficiency, maneuverability, quietness, and speed of the propulsion.

Research Concentration Areas: Suggested research areas include:

- 3D, time-resolved computational and experimental investigations into the kinematics, morphometrics and mechanical properties (such as flexibility and compliance) and their relationship to the 3D wake structure and efficiency, using a multidisciplinary approach, for example, structures/mechanics, materials, hydrodynamics, computational methods and underwater optical imaging.

- Exploration of the relationship between propulsor hydroelastic effects and efficiency using a combined experimental and computational approach.
- Research into effects of active and passive flow control around propulsive surface using a combined experimental and computational approach.
- Non-traditional methods of propulsion which may include but is not limited to bio-inspired methods and unsteady propulsion.

Anticipated Resources: It is anticipated 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 funded faculty. 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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