BROAD AGENCY ANNOUNCEMENT (BAA)

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. Request for same will be disregarded.

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 participating DoD agencies 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).

Potential offerors may obtain information on ONR programs and opportunities by checking the ONR website at http://www.onr.navy.mil. Specific information about BAAs and amendments and updates to this BAA will be found at that site under the heading "BAAs".

I. GENERAL INFORMATION

1. Agency Name

Office of Naval Research
875 North Randolph Street - Suite 1425
Code 03R
Arlington, VA 22203-1995

2. Research Opportunity Title

Multidisciplinary University Research Initiative (MURI)

3. Program Name

Fiscal Year (FY) 2010 Department of Defense Multidisciplinary Research Program of the University Research Initiative

4. Research Opportunity Number

BAA 10-002

5. Response Date

White Papers: Friday 11 December 2009

Full Proposals: Tuesday 02 March 2010

6. Research Opportunity Description

Synopsis

The MURI program supports basic science and/or engineering research 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 that intersect more than one traditional science and engineering discipline to address issues of critical concern 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." (www.defenselink.mil/comptroller/fmr/02b/02b_05.pdf). The DoD's basic research program invests broadly in many specific fields to ensure that it has early cognizance of new scientific knowledge.

The FY 2010 MURI competition is for the 30 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 proposer 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 (10) should be submitted to The Office of Naval Research:

(1) Optical Metamaterials
(2) Adaptive Cognitive Maps for Autonomous Systems
(3) Non-linear Mediums Converting Frequencies of Propagating E/M and Pressure Waves
(4) Biofuels: Microbial Communities, Biogeochemistry and Surface Interactions
(5) Design, Synthesis, and Characterization of Electro-Active Polymers for Dielectric Energy Storage
(6) Reasoning for Image Understanding in Uncertain Environments
(7) Fundamental Study of High- and Low-K Dielectrics for III-V Electronic Devices
(8) Provably-Safe Perception-Based Control for Autonomous UAS Operations around Complex, Unstructured Terrain
(9) Dynamical Systems Theory in 4D Geophysical Fluid Dynamics
(10) Hyperspectral, Radar and EO/IR Signatures in the Littorals

White papers and Full proposals addressing the following topics (11) through (20) should be submitted to the Air Force Office of Scientific Research (AFOSR):

(11) Novel Catalytic Mechanisms for the Chemical Reduction of Carbon Dioxide to Energy-Dense Liquids
(12) Third Order Nonlinear Optical Organics
(13) Fundamental Processes in High-Temperature Gas-Surface Interactions
(14) Propagation of Ultrashort Laser Pulses through Transparent Media
(15) Superconducting Semiconductors
(16) Human-Machine Adversarial Networks
(17) Biologically-Engineering of Adherent / Spectroscopically Interrogated Microstructures
(18) Control of Information Collection and Fusion
(19) Stable Metrics for Global Inference in Social Networks to Predict Collective Behavior
(20) Solid State Cooling

White papers and full proposals addressing the following topics (21) through (30) should be submitted to the Army Research Office (ARO):

(21) Neuronal Behavior in Primary Blast
(22) Identifying and Extracting the Mathematical Signatures of Prokaryotic Activity in DNA; Developing a Theoretical Foundation for Predicting DNA Stability
(23) Tomography of Social Networks of Asymmetric Adversaries
(24) Adaptive Perception and Agile Autonomy in Severe Environments
(25) Structured Modeling for Low-Density Languages
(26) Directed Self-Assembly of Reconfigurable Materials
(27) "Atomtronics": A generalized electronics
(28) Bio-Electronic Templates for Interfacing to the Nanoscale
(29) Ion Transport In Complex Heterogeneous Organic Materials
(30) Defect Reduction in Superlattice Materials

Proposals from a team of university investigators may be warranted because 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 must name one Principal Investigator (PI) as the responsible technical point of contact. Similarly, one institution will be the primary awardee for the purpose of award execution. The PI must 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, must 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 257
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 Specialist
Contract and Grants Awards Management, Code ONR 0251
Office of Naval Research
875 North Randolph Street, Suite W1273
Arlington, VA 22203-1995
E-Mail: lynn.christian@navy.mil

Secondary:
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

8. Instrument Type(s)

It is anticipated that all awards resulting from this announcement will be grants.

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:
Air Force Office of Scientific Research
875 North Randolph Street
Suite 325, Room 3112
Arlington, VA 22203-1768

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

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 2-year option period to bring the total maximum term of the award to five years. The base and option period will be incrementally funded.

Total amount of funding for five years available for grants resulting from this MURI BAA is estimated to be about $222M, pending out-year appropriations. MURI awards are $1.5M per year, with the actual amount contingent on availability of funds, the specific topic, and the scope of the proposed work. With very few exceptions an individual award may not exceed $1.5M per year. It is strongly recommended that potential proposers communicate with the Program Topic Chief 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.* Ineligible organizations (e.g., industry, DoD laboratories, Federally Funded Research and Development Centers (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.

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 them to submit full proposals. The Topic Chief may also on occasion provide feedback encouraging reteaming to strengthen a proposal.

White papers arriving after the deadline may not receive feedback prior to full proposal submission. However, all full proposals submitted under the terms and conditions cited in the BAA will be reviewed.

Due Date: The due date for white papers is no later than 4:00 P.M. (Eastern Time) on Friday, 11 December 2009.

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), via a commercial carrier or may be hand delivered to the attention of a responsible Research Topic Chief at the agency specified for the topic.

Evaluation/Notification: Initial evaluations of the white papers will be issued on or about

*To the extent that it is a part of a U.S. institution of higher education and is not designated as an 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 Broad Agency Announcement, to include the potential impact on the institution's ability to perform defense-relevant research and to train students in science and/or engineering.

05 January 2010.

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.

Registration Requirements for Grants.gov: There are several one-time actions you must complete in order to submit an application through Grants.gov (e.g., obtain a Dun and Bradstreet Data Universal Numbering System (DUNS) number, register with the Central Contract Registry (CCR), register with the credential provider, and register with Grants.gov). See www.grants.gov/GetStarted to begin this process. Use the Grants.gov Organization Registration Checklist at www.grants.gov/assets/OrganizationRegCheck.doc to guide you through the process. Designating an E-Business Point of Contact (EBiz POC) and obtaining a special password called an MPIN are important steps in the CCR registration process. Applicants, who are not registered with CCR and Grants.gov, should allow at least 21 days to complete these requirements. It is suggested that the process be started as soon as possible.

Questions: 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 or support@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. The full proposal submissions will be protected from unauthorized disclosure in accordance with FAR 15.207, applicable law, and DoD regulations. Proposers are expected to appropriately mark each page of their submission that contains proprietary information. Grants awarded under this announcement will be unclassified.

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 for which you are applying.

White paper format should be as follows:

- Paper Size - 8.5 x 11 inch paper
- Margins - 1 inch
- Spacing - single
- 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 papers exceeding the page limit may not be evaluated.

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.

White papers may be submitted via e-mail, via the United States Postal Service (USPS), via a commercial carrier or may be hand delivered to the attention of a responsible Research Topic Chief at the agency specified for the topic. For hard copy submissions, use the addresses provided in Section IV entitled, "Application and Submission Information" paragraph number 6 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.

Copies – one (1) original and two (2) copies.

b. Grants.gov Full Proposal Submission: Content and Format of Applications

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 announcement. 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 for which you are applying.

Content and Form of Application – SF 424 (R&R)

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)

Complete this form first to populate data in other forms. 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).

Form Research & Related Other Project Information.

Complete questions 1 through 6 and attach files. The files must comply with the following instructions:

Project Summary/Abstract (Field 7 on the Form)

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, 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."

Project Narrative (Field 8 on the form)

<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, and curriculum vitae are excluded from the page limitations. Full proposals exceeding the page limit may not be evaluated.

<u>Include the Following in Field 8</u>

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

- <u>Table of Contents</u>: List project narrative sections and corresponding page numbers.

- <u>Statement of Work</u>: A Statement of Work (SOW) should clearly detail the scope and objectives of the effort and the specific research to be performed under the grant if the proposal is selected for funding. It is anticipated that the proposed SOW will be incorporated as an attachment to any resultant award instrument. To this end, this project narrative must include a severable self-standing SOW, without any proprietary restrictions, which can be attached to a grant award.

- Technical Approach: Describe in detail the basic science and/or engineering research to be undertaken. State the objective and approach, including how data will be analyzed and interpreted. Discuss the relationship of the proposed research to the state-of-the-art knowledge in the field and to related efforts in programs elsewhere, and discuss potential scientific breakthroughs. Include appropriate literature citations/references. Discuss the nature of expected results. Discuss potential applications to defense missions and requirements. Describe plans for the research training of students. Include the number of full time equivalent graduate students and undergraduates, if any, to be supported each year. Discuss the involvement of other students, if any.

- Project Schedule, Milestones and Deliverables: A summary of the schedule of events, milestones, and a detailed description of the results and products to be delivered.

- Management Approach: A discussion of the overall approach to the management of this effort, including brief discussions of: required facilities; relationships with any subawardees and with other organizations; availability of personnel; and planning, scheduling and control procedures.

  (a) Describe the facilities available for the accomplishment of the proposed research and related education objectives. Describe any capital equipment planned for acquisition under this program and its application to the proposed research. If possible, budget for capital equipment should be allocated to the first budget period of the grant. Include a description of any government furnished equipment/hardware/software/information, by version and/or configuration that are required for the proposed effort.

  (b) Describe in detail proposed subawards to other eligible universities or relevant collaborations (planned or in place) with government organizations, industry, or other appropriate institutions. In particular, describe how collaborations are expected to facilitate the transition of research results to applications. Descriptions of industrial collaborations should explain how the proposed research will impact the company's research and/or product development activities. 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 Program Topic Chief. Briefly summarize the qualifications of the Principal Investigator and other key investigators to 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.

All applications should be in a single PDF file. To attach a Project Narrative in Field 8, click "Add Attachment."

Bibliography & References Cited (Field 9 on the form)

This field not required.

Facilities & Other Resources (Field 10 on the form)

This field not required.

Equipment (Field 11 on the form)

This field not required.

Other Attachment (Field 12 on the form)

Attach budget proposal at field 12. You must provide a detailed cost breakdown of all costs, by cost category, by the funding periods described below, and by task/sub-task corresponding to the task number in the proposed Statement of Work which was provided in Field 8 of the Research and Related Other Project Information Form. The option must be separately priced.

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 August 2010. For the three-year base grant, the cost should be broken down to reflect funding increment periods of:

(1) Two months (01 August 10 to 30 Sep 10),
(2) Twelve months (01 Oct 10 to 30 Sep 11),
(3) Twelve months (01 Oct 11 to 30 Sep 12), and
(4) Ten months (01 Oct 12 to 31 July 13).

Note that the budget for each of the calendar periods (e.g. 01 August 10 to 30 Sep 10) 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) Two months (01 August 13 to 30 Sep 13),
(2) Twelve months (01 Oct 13 to 30 Sep 14), and
(3) Ten months (01 Oct 14 to 31 July 15).

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 to be submitted by the subrecipient(s). Fee/profit is unallowable. The subawardee's or subrecipient's cost proposal can be provided in a sealed envelope with the recipient's cost proposal or via e-mail directly to both the Program Officer and the business point of contact at the same time the prime proposal is submitted. The e-mail should identify the proposal title, the prime Offeror and that the attached proposal is a subcontract. A proposal and supporting documentation must be received and reviewed before the Government can complete its cost analysis of the proposal and enter negotiations.

• 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.

Cost breakdown by Government fiscal year and task/subtask

Funding breakdown by task/sub-task corresponding to the task number in the proposed Statement of Work which was provided in Field 8 of the Research and Related Other Project Information Form must also be attached.

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, ARO or AFOSR 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.

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.)

Number 3 – The third notice is an acknowledgment of receipt in e-mail form from the designated agency within ten days from the proposal due date. 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**	27 November 2009*	2:00PM Eastern Time
White Papers Due	11 December 2009	4:00 PM Eastern Time
Notification of Initial DoD Evaluations of White Papers	05 January 2010**	
Questions Regarding **full proposals**	02 February 2010*	2:00PM Eastern Time
Full Proposals Due	02 March 2010	4:00 PM Eastern Time
Notification of Selection for Award	15 May 2010**	
Start Date of Grant	01 August 2010*	

*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.

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. The following alternative to submitting proposals to grants.gov for consideration by ONR is provided for use on this BAA. Proposals using the alternative submission process will be accepted by ONR only if grants.gov is not accepting the proposal and the offeror has called the grants.gov helpline and received an unresolved trouble ticket/case number. If grants.gov has not validated your proposal submission via email, call grants.gov to obtain a trouble ticket; emails indicating receipt of the application and rejection will not be accepted in place of a grants.gov trouble ticket.

Upload the proposal using the following website: http://onroutside.onr.navy.mil/aspprocessor/BAAPE/

Please use this form to upload your grant proposal directly to the Office of Naval Research. All fields in the form are required to be completed. Your completed package should also include a signed, scanned proposal cover sheet with the signature of your authorized organizational representative as part of the "Attachments Form'. Submit one file per proposal in PDF format. **DO NOT submit any parts of the proposal separately. Technical proposals, endorsements, etc. should be on the grants.gov ATTACHMENTS form.**

Use the naming convention below for all uploaded proposals

(ONRBAA10-002_Topic_Lead PI_ University.pdf

Once a document has been submitted, a "Thank –You" page will appear and an email will be sent to the address provided.

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 of 4:00 (Eastern Time) 02 March 2010.

c. 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@us.army.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 specified in the BAA.

6. Address for Submission of Hard Copy White Papers

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

Hard copies of white papers topics (1) to (10) 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 257*
Arlington, VA 22203-1995
Point of Contact: Dr. William Lukens
Email: 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.

Important Notes Regarding Submission of White Papers:

If the Offeror is using USPS, please allow an additional five (5) business days for the package to be delivered to this address due to USPS mail being sent to a central location for special processing before it is sent to this address.

Hard copy white papers addressing topics (11) to (20) 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
Point of Contact: Dr. Spencer Wu
703-696-7315
Email: spencer.wu@afosr.af.mil

Hard copy white papers addressing topics (21) to (30) should be sent to the 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 (FY10 MURI)
P. O. Box 12211 Research Triangle Park,
NC 27709-2211
Email: larry.russelljr@us.army.mil

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

U.S. Army Research Office (FY10 MURI)
For white papers include: ATTN: (list name of responsible Research Topic Chief)
4300 S. Miami Blvd
Durham, NC 27703-9142
919-549-4211
Email: larry.russelljr@us.army.mil

NOTE: White Papers sent by fax will not be considered.

V. EVALUATION INFORMATION

1. Evaluation Criteria

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 merit (criterion 1, below) and relevance and potential contribution to DoD (criterion 2, 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) relevance and potential contributions of the proposed research to the topical research area and to DoD missions;

(3) potential impact on the institution's ability to perform defense-relevant research and to train, through the proposed research, students in science and/or engineering (for example, by acquiring or refurbishing equipment that can support DoD research and research-related educational objectives); and

(4) the qualifications and availability of the Principal Investigator and key co-investigators.

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

(5) the adequacy of current or planned facilities and equipment to accomplish the research objectives;

(6) the 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) the 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.

Full proposals will be evaluated by an evaluation panel chaired by the responsible Research Topic Chief for the particular topic and will consist of technical experts who are Government employees. Evaluation panel members are required to sign "no conflict of interest" statements.

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.

3. Selection Process

Full proposals will undergo a multi-stage evaluation procedure. The respective evaluation panels will review proposals first. Findings of the evaluation panels will be forwarded to senior DoD officials who will make funding recommendations to the awarding officials.

VI. AWARD ADMINISTRATION INFORMATION

1. Administrative Requirements –

Central Contractor Registry (CCR) - Successful Offerors not already registered in the CCR will be required to register in CCR prior to award of any grant. Information on CCR registration is available at http://www.onr.navy.mil/02/ccr.htm.

• Certifications – Grants:

Grant awards greater than $100,000 require a certification of compliance with a national policy mandate concerning lobbying. Grant applicants shall provide this certification by electronic submission of SF424 (R&R) as a part of the electronic proposal submitted via Grants.gov (complete Blocks 18 and 19); The following certification applies to each applicant seeking federal assistance funds exceeding $100,000:

CERTIFICATION REGARDING LOBBYING ACTIVITIES

(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.
Grants not through Grants.gov
Proposers seeking grants who have received Grants.gov waiver approval for awards greater than $100,000 shall complete and submit electronic representations and certifications at the Contracts and Grants Section of the ONR Home Page at http://www.onr.navy.mil/02/rep_cert.asp .

3. 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 reports as requested by the Research Topic Chief.

VII. OTHER INFORMATION

1. Government Facilities and Resources

Government research facilities and operational military units are available and should be considered as potential government 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 AALAC 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 documentation, contact the ONR Animal Use Administrator at (703) 696-4046.

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.

3. Recombinant DNA

Proposal 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 RDT & E communities with use-access to very powerful high performance computing systems. Awardees of grants, 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. Submission of Questions

Any questions regarding this solicitation must be provided to the Science and Technology Point of Contact and/or Business Point of Contact listed in this solicitation. All questions shall be submitted in writing by electronic mail.

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/02/baa/

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VIII. SPECIFIC MURI TOPICS

ONR FY2010 MURI TOPIC # 1

Submit white papers and proposals to the Office of Naval Research

Optical Metamaterials

Background: The field of electromagnetic metamaterials has been rapidly developing in recent years, promising to deliver new materials with exotic properties generally unattainable in nature. One interesting characteristic of metamaterials is a strong magnetic response, which may lead to negative index materials and the promise of perfect lenses, sub-wavelength transmission lines, and agile antennas. Zero index materials may be perfectly reflective and may also enhance wave coupling in waveguides. Composites of negative and positive index materials could theoretically be perfectly absorbing or emissive, enabling highly efficient photovoltaics and thermal control systems. The ability to demonstrate sub-micron spatial resolution over a experimentally significant area will require use of scalable methodologies such as thin film processes coupled with advanced mathematical and control models. Fundamental advances are required to improve the regularity and fidelity of coatings and structures synthesized by three-dimensional photolithographic methods. Novel techniques such as nanoimprint lithography are just emerging and would be further explored as well as other methodologies.

Negative index has been demonstrated at microwave frequency by combining split ring resonators with thin wires or dipoles. Expanding the ability of these structures to operate at higher frequencies is not practical due to reduction in the conductivity of the metals typically used to fabricate them. Plasmonic metamaterials operate in the wavelength regime where the kinetic energy of the oscillating free electrons is comparable in magnitude to the energy of the electric field, thus making them more difficult to model and fabricate. Accurate three-dimensional models of these materials are necessary to design unusual and unnatural electromagnetic properties, such as negative permittivity and negative permeability. An understanding of plasmon tunneling and propagation is critical to future developments in this field. The use of non-linear materials that allow the incorporation of tunability and gain are at the forefront of metamaterials research. Of interest for this MURI is a fundamental understanding of metamaterials operating in the plasmonic regime that can lead to new designs and synthesis techniques that enable submicron spatial control in three dimensions. Scalable, fault-tolerant architectures that can lead to large-area metamaterials are desirable. Advances in the understanding of mechanisms that minimize loss and increase the operating frequency are critical for future applications. Fundamental advances are required to improve the speed and throughput of three-dimensional photolithographic techniques.

Objective: The objective of this MURI is to discover new constructs for metamaterials at visible and infrared wavelengths (0.4 – 12 microns) and to demonstrate novel nanolithographic techniques for their realization over large-area and in three-dimensions. A multidisciplinary research effort will bring physics, chemistry, materials science, and electrical engineering together to design and synthesize three-dimensional metamaterials.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) Theoretical tools (analytic and simulation) to design and characterize optical metamaterials, with particular emphases on understanding bandwidth and loss; (2) Nanofabrication techniques to build uniform structures with submicron composite features; (3) Synthesis of active metamaterials, which may be tunable, have gain, or show broadband properties; (4) Exploration of characterization techniques to better understand the properties, benefits and fundamental limits of metamaterials.

Impact: Metamaterials offer a means of controlling light and sound propagation not available through naturally occurring materials. Potential applications include low observable coatings, low loss waveguides for high power optical transmission, and sub-wavelength imaging optics. In order to realize such applications, fabrication methods scalable to large areas are necessary.

Research Topic Chiefs: Dr. Mark S. Spector, ONR, 703-696-4449, mark.spector@navy.mil

ONR FY2010 MURI TOPIC # 2

Submit white papers and proposals to the Office of Naval Research

Adaptive Cognitive Maps for Autonomous Systems

Background:
Recent research has revealed that the brain's hippocampal and entorhinal systems provide an intrinsic metric of space and mechanisms to guide navigation and exploration of space. The entorhinal cortex contains "grid cells" which discharge when an animal is in a repeating set of locations within the environment, laid out in a hexagonal array. The grids are multi-scale and are capable of experience-dependent rescaling. The entorhinal neurons project to the hippocampus where neurons encode speed and the head angle as well as features of specific locations, such as visual landmarks and obstacles. This hippocampal place and heading representation is encoded in the phase precession of oscillations in this neural system Since these brain structures are also critical in memory processes, including episodic and trajectory memory, and integrate information from multiple cortical regions including polymodal association areas representing spatial and temporal context and highly specific information on item identity, this research has generated excitement on the prospects of characterizing the neural basis of cognitive maps.

Objective:
Identify the architectures and computational principles by which the parahippocampal region generates spatial representation, enables 2D and 3D navigation, and links visual imagery, landmarks, event memory and semantic information in cognitive maps.

Research Concentration Areas:

1) Non-linear dynamic models of the neural networks generating the grid cell representation of space and navigation.
2) Elucidation of the mechanisms by which visual inputs from the environment keep grid cell representations registered to the real world and how visual landmarks and objects are linked to spatial representations.
3) Computational models for navigation of autonomous systems based on the sensory and motor system links to the multi-scale parahippocampal grid and location networks.
4) Experimental and theoretical characterization of how the neuroscience of grid and place coding in the parahippocampal region informs human spatial representations, navigation and spatially linked semantic and visual information.

Impact:
A deeper understanding of natural neural-based spatial mapping and navigation would produce more robust approaches to robotic navigation and help bridge the semantic gap between geometric based robotic systems and human-level spatial reasoning. This will enable cognitively-compatible control and interaction of humans and autonomous systems, and robots capable of spatial cognition.

Research Topic Chief: Dr. Thomas McKenna, ONR, 703-534-3795, tom.mckenna@navy.mil

ONR FY2010 MURI TOPIC # 3

Submit white papers and proposals to the Office of Naval Research

Non-linear Mediums Converting Frequencies of Propagating E/M and Pressure Waves

Background: Sub milli-meter EM wavelengths and equivalent wavelength pressure pulses (ultrasound) propagate very poorly in atmosphere, primarily due to absorption with molecular rotation and vibration states. However, these short wavelength energies afford good resolution capabilities, strong target interactions, and unique spectroscopic interrogation. For the EM energies, being selectively absorbed by targets can help detect those targets because of stimulated emissions (release of vapors) or increased thermal images. For ultrasound energies, being similar sized to mechanical features (boundaries or interfaces between crystals and defects in structures) would cause acoustic impedance mismatches perhaps leading to localized energy absorption and stimulated release of signatures, but more directly induce slight mechanical vibrations that can be detected by higher optical frequencies or lower frequency radars. Yet to use sub-mm propagating energies requires overcoming the atmospheric propagation losses. Non-linear mediums (atmospheric plasma air break downs, glass tinted to absorb UV, composite structures and other entities where the dielectric coefficient is non-linear) can, in principle, convert mm-energies to shorter wavelengths by mixing or generating multiple harmonics. Similarly, non-linear media might mix higher optical or FIR down to lower frequencies. If achievable, this would greatly aid many stand-off detection and imaging systems that discriminate targets by their sub-mm absorptance. Also, this understanding potentially benefits sonar detection in littoral settings.

Objective: This MURI unites the physical sciences of propagating EM and acoustic energy, material sciences of material interactions and energy absorption, sciences of non-linear mediums including arc-plasmas, and computational/numerical sciences and simulations. The research objective is to understand how non-linear media convert and interact with sub-mm EM radiation and acoustic waves, how these short wave length energies couple into solid materials and composites, and to determine the physical mechanisms governing these processes. A specific research goal is to determine if non-linear conversion can avoid atmospheric absorption phenomena that limits stand-off material detection and identification using sub-mm wave lengths. An innovative aspect of this research is to combine both forms of sub-mm propagating energies (ultrasound and e/m waves) and research how combinations effect material interaction and response. Similar investigations will be devoted to how the propagating energy pulse duration (band-width), repetition-rate, waveform and wavelengths, influence non-linear processes and target interactions-responses. The basic research will balance analysis, numerical simulations and proof-of-concept experimentation.

Research Concentration Areas: (-1-) E/M and ultrasonic physics and solid state chemical science: Sub-mm energy material interactions, absorptions, and energy conversion need fundamental understanding. (-2-) Material science: Basic research on mechanisms by which non-linear mediums generate sub-mm wavelengths. (-3-) Simulations and theoretical analysis will precede proof-of-concept experiments.

Impact: The understanding gained through these fundamental studies on non-linear mediums will benefit detection, imaging, limited-range secure communications and other scenarios where propagating energies (e/m & sound waves) cover tactical distances and then be frequency shifted to resonantly interact on specific targets and receivers.

Research Topic Chiefs: Dr. D. Prono, ONR, pronod@onr.navy.mil, 703-696-3073

ONR FY2010 MURI TOPIC # 4

Submit white papers and proposals to the Office of Naval Research

Biofuels: Microbial Communities, Biogeochemistry and Surface Interactions

Background: Bio-derived hydrocarbon fuels need improvement to meet critical Navy requirements for use in military platforms (air, land, and sea). Navy policy currently prohibits the use of biofuels for tactical platforms due to storage and operational instability. Alcoholic fuels such as ethanol are undesirable, due to their adverse impact to fuels logistics and to their lack of energy density that would severely impact platform range.

Two factors that impede use of biofuels for tactical platform use are (1) replicating the natural complexity of petroleum-based hydrocarbon fuels and (2) the use of compensated seawater fuel tanks and constant exposure to a high salt environment. The latter factor introduces active microbial communities that degrade hydrocarbon fuels and promote (bio)corrosion.

Shifts within microbial consortia to changing environmental conditions are agile, and reflect natural adaptive capabilities and ability to communicate at an intra- and intercellular level. The microbial metabolism of fuel components produces key metabolites, which could help elucidate the critical organic compounds that support the entire microbial community. Identification of microbes and key pathways involved in biodegradation or biotransformation of biofuels and resultant biocorrosion processes is needed to understand the ramifications of utilizing biofuels for Navy tactical platforms. Variations among feedstock sources of biofuels, esterification and by-product removal methods,and storage conditions introduce other potential factors that can influence biodegradation and the rate and extent of biocorrosion.

Objective: To explore molecular- and micro-biological approaches to establish the key organisms, reactions and mechanisms involved in biocontamination and subsequent biocorrosion processes in bio-derived hydrocarbon fuels.

Research Concentration Areas: This program will require a multidisciplinary (molecular biology, fuel chemistry, analytical biochemistry, microbiology, surface and interfacial science, mathematical modeling, electrochemistry, corrosion) team that can identify and characterize the biofuel components and/or microbial metabolites that lead to fuel contamination, degradation and biocorrosion under varying biogeochemical and environmental conditions. Areas of interest include, but are not limited to, the following: (1) metabolic profiling and characterization of microbial communities/contaminants in biofuels from differing feedstocks/processing approaches, (2) comparative analysis of multiple biofuels/petroleum-based fuels and components subjected to microbial inocula under various biogeochemical and environmental conditions, (3) elucidation of key microbial interactions (e.g., syntrophy) within communities and with substrates (e.g., coated steel) under various conditions, (4) flux analysis of metabolites, intermediates or species that influence rate and extent of biocontamination, biodegradation and biocorrosion; and (5) bioprocess simulation. The use of molecular dynamics and physics-based, multi-scale mathematical modeling and simulations coupled with experimental validation will establish the fundamental science base for understanding issues with current biofuel production or formulation strategies that limit their use in naval platforms. This information will inform next- generation stable, high-performance synthetic biofuels.

Impact: The detailed microbiological, biochemical and analytical chemistry approach when combined with mathematical modeling tools will provide a comprehensive perspective on the metabolic capabilities and functioning of microbial communities in biofuel/ biofuel blends and storage facilities. This increased understanding of *in-situ* biodegradation potential will lead to more rapid and specific tools for monitoring of existing fuel storage facilities, as well as assessing risk of contamination prior to blending. The establishment of the key mechanisms and metabolic pathways will lead to the creation of domestically produced biofuels that meets the strict Navy fuel standards and also provide reliable sources for commercial usage.

Research Topic Chiefs: Dr. David Shifler, ONR, david.shifler@navy.mil, 703-696-0285
Dr. Linda Chrisey, ONR, linda.chrisey@navy.mil, 703-696-4504
Dr. Michele Anderson, ONR, michele.anderson1@navy.mil, 703-696-1938

ONR FY2010 MURI TOPIC # 5

Submit white papers and proposals to the Office of Naval Research

Design, Synthesis, and Characterization of Electro-Active Polymers for Dielectric Energy Storage

Background: Capacitors can occupy more than 50 volume percent of large electrical systems for pulsed power and power conditioning operations. State-of-the-art capacitors are based on metalized biaxially oriented polypropylene films. The lamellar morphology imparts high dielectric breakdown strength, but the low permittivity limits the energy storage density. Many approaches to raising the permittivity add to dielectric losses or lower the break down strength. Polyvinylidene fluoride (PVDF) has a permittivity about 6 times greater than that of polypropylene as a result of a polar crystalline phase. These crystallites can be oriented by an electrical field, but the crystallites don't completely randomize on removal of the field and there is large remnant polarization. Thus, the potential for higher energy storage density in these materials is not realized. Recent work has shown that disrupting the crystal packing can result in smaller crystallites and a reduced energy difference between polar (extended chain) and nonpolar (helical chain) crystalline forms that allow the applied field to store energy in the polarization of the polymer chain. There are still dielectric loss issues to deal with here, but this unconventional approach has the potential to improve energy storage in an easily processed film by an order of magnitude. The goal of this program is to discover other such unconventional materials and mechanisms that can be developed in easily processed polymer films to increase energy storage capability with very low dielectric losses.

Objective: The objective of this MURI is to open existing bottlenecks in polymer dielectric materials design by developing *rationale design strategies* rather than relying upon accidental discovery or discovery based on "intuition". The rational design strategy, called computer-aided materials design (CAMD), is similar to that used so successfully in the pharmaceutical companies for drug design, e.g., QSAR, but has yet to be used by DoD. Any salient computer-based design strategy such as QSAR, quantum theory, informatics, etc., is acceptable for this project. Design, synthesis, and testing of dielectric materials for capacitors having greater than 20 J/cc storage capability with less than 0.1% dielectric loss and operational stability to greater than 150C is a target goal while exploring basic scientific principles. The feedback between Design, Synthesis, and Characterization components should lead to new dielectric materials and a better understanding of the chemical and morphological origins of dielectric permittivity and resistance to dielectric breakdown.

Research Concentration Areas: A balanced, interdisciplinary program consisting of (1) Computational chemistry/physics; (2) Polymer synthesis and chemical characterization; (3) processing of the polymer into thin films with full morphological and dielectric characterization.

Impact and Relevance: The PVDF system with small crystal domains is the first example of enhanced permittivity in polymers due to a field-induced phase change. There must be other, as yet discovered materials with even better dielectric storage density. The computational methodology we propose to use will allow us to find those materials more quickly than traditional methods based on first principles calculations and will allow us to further enhance performance using rational design principles.

Research Topic Chief: Paul Armistead, ONR, paul.armistead@navy.mil, 703-696-4315
Kenny Lipkowitz, ONR, Kenny.lipkowitz@navy.mil, 703-696-0707

ONR FY2010 MURI TOPIC # 6

Submit white papers and proposals to the Office of Naval Research

Reasoning for Image Understanding in Uncertain Environments

Background: Current vision systems still perform inadequately in uncertain, uncontrolled environments and are far inferior to human-level capability in image understanding, scene recognition, recognition and localization of objects in the scene, activity recognition, inferring relationships among entities, discrimination between background and foreground and disregarding unimportant information (which depends on the task), and succinct descriptions of the image in natural language. The superior visual performance of humans is attributed to their complex and massive stores of knowledge and their ability to reason about the structure of the scene and objects. Many issues in image understanding (ranging from errors in low-level processing to segmentation, activity recognition, and uncertain and incomplete information) can be improved or alleviated by reasoning. Recent work demonstrated that by using reasoning with contextual information, vision algorithms can indeed extract more information from images, leading to improved recognition rates and scene structure estimate from a single image. However, these advances are generally based on ad hoc and heuristic methods. In this research topic we want to develop principled approaches that address important issues including (i) identification of appropriate reasoning methods and in what way and how frequently the reasoning module(s) should interact with image information, (ii) defining the content and organization of visual knowledge bases, (iii) representing mission focus and it's interaction with the various processing stages, and (iv) methods to control errors from lower level processing and guaranteeing that the system arrives at the correct interpretation of the image.

Objective: Develop principles, computational methods, and architecture to enable vision systems to seamlessly integrate low-level image data and high-level knowledge, reason with images, and describe images. These methods should be able to describe the spatio-temporal relationship of objects in the scene in ways that are similar to and consistent with the descriptions produced by humans.

Research Concentration Areas: Image understanding requires multidisciplinary research in imaging science, computational sciences, cognitive science, and artificial intelligence. We encourage multidisciplinary proposals that address one or more of the following areas: (a) Investigate entity attributes and their representations needed in visual knowledge bases. (b) Develop methods for automatically building, organizing, and expanding visual knowledge bases. (c) Develop automated methods for learning representations of objects, activities, relationships, image contexts, etc. (d) Develop visual reasoning methods that exploit spatial, temporal, relational, behavioral, contextual, and other cues. (e) Develop meta-reasoning methods so that recognition algorithms can assess their own performance and seek additional information when needed. (f) Develop a grammar for image description that supports interaction with humans.

Impact: Limited DOD manpower makes it impossible to analyze the majority of the sensor data that is produced. This creates a serious deficiency in performing a host of missions, in particular adaptive, persistent surveillance where massive amounts of heterogeneous sensor data, including image/video data, is collected. The results of this MURI topic will alleviate these problems arising in a network of imaging sensors, autonomous robots, and a wide range of DOD applications where information fusion occurs.

Research Topic Chiefs: Dr. Behzad Kamgar-Parsi, ONR, 703-696-5754,
behzad.kamgarparsi@navy.mil
Dr. Paul Bello, ONR, 703-696-4318, paul.bello@navy.mil

ONR FY2010 MURI TOPIC # 7

Submit white papers and proposals to the Office of Naval Research

Title: Fundamental Study of High- and Low-K Dielectrics for III-V Electronic Devices

Background: In the mid-eighties Silicon Nitride (Si_3N_4) was empirically developed as a dielectric coating for GaAs devices and circuits. Almost by default, Si_3N_4 was adopted as the primary dielectric for all III-V technologies including GaAs, InGaAs, InP, InGaSb, and GaN. This widespread application of Si_3N_4 has expanded the function of the film from not only dielectric coatings but also to serve as: surface passivation (particularly Gallium Nitride), gate insulator, and capacitor dielectric, among other roles. In the case of materials like GaN for which the dielectric must now genuinely passivate the surface, Si_3N_4 is a problematic choice due to the poorly controlled composition and defect properties using available deposition technologies. The uncontrolled stress properties in as-deposited Si_3N_4 films are well known to induce piezoelectric effects in III-V materials, particularly Gallium Nitride, which impact both device stability and reliability. Given all the diverse requirements for dielectrics in III-V technology, it is unlikely that Si_3N_4 is the best choice. The potential alternatives to Si_3N_4 have not been evaluated systematically on a basic materials level. Very little work has been done to study the interaction between alternative dielectrics and semiconductors on a chemical and mechanical level which can impact device performance by introducing uncontrolled channel charge variations. Fortunately, the need to study these basic film properties has coincided with the emergence of a powerful new deposition tool. The advent of Atomic Layer Deposition (ALD) has provided a well-controlled method to deliver an array of precisely tailored dielectrics. This combination of emerging need and new capability provides an outstanding opportunity to perform basic studies of material properties with the potential for wide-ranging benefits to device performance.

Objective: This MURI is to research alternative high- and low-K dielectrics for use in the III-V electronics technologies. The goals are to develop a detailed understanding of the fundamental properties of these dielectrics, investigate approaches to control these properties, and expand our understanding of how the properties of the dielectrics impact the device performance (how they can be tailored to achieve the desired device performance).

Research Concentration Areas: Research areas should include but not be limited to, the following: the identification of alternative high- and low-K dielectrics, the properties of these dielectrics as a function of growth conditions on a platform compatible with modern manufacturing techniques, the development of an expanded set of precursors that will allow for the growth of a wider spectrum of dielectrics on the platforms of choice, a detailed understanding of the impact of the dielectric properties on the active and passive circuit components, an understanding of how the surface properties of the device material influence the dielectric, an understanding of how defects and intentional and unintentional impurities in the dielectric impact the device performance (negatively and positively) and an understanding of the mechanical properties of the dielectric and an approach to control these various properties so as to match the needs of the underlying structures.

Impact: This work will enable a broad class of both analog and digital devices and circuits with enhanced performance, improved robustness and reliability.

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ONR FY2010 MURI TOPIC # 8

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Provably-Safe Perception-Based Control for Autonomous UAS Operations around Complex, Unstructured Terrain

Background: There are currently a number of research efforts examining the use of on-board perception to increase the autonomous capability of unmanned air systems. However, many of these efforts take advantage of the fact that unmanned air systems typically operate in fairly uncluttered, simple environments with few types of objects. Further, many of the approaches used in these efforts involve highly complex techniques that cannot be proven to be safe for use in applications that involve close proximity to humans or manned assets. This is a problem as there is interest in autonomous control systems that can make control decisions based on a rich understanding of much complex, uncertain, and unstructured environments that may include humans. One example of this would be autonomous landing of an unmanned air system for casualty evacuation in a non-cooperative environment including a variety of positive and negative obstacles, a lack of flat ground, environmental disturbances (updrafts, downdrafts, turbulence, winds), and various types of terrain (mud, sand, water, foliage, etc). This might even require some degree of direct interaction with the environment to determine a safe landing place. Another example would be autonomous control of an air system under a forest canopy. This would require understanding numerous complex and cluttered obstacles in varying lighting conditions as well as the ability to make rapid and appropriate decisions to avoid collisions and deal with disturbances.

While these are very difficult problems, there are examples of systems that are able to operate effectively in such environments. This includes birds, bats, insects, and in some cases, skilled human piloting of manned and remote-controlled aircraft. However, while specific examples of such systems have been well-studied, there has been a lack of broad comparative studies to determine general principles across species and how different solution approaches relate to particular factors (e.g., the physical terrain, atmospheric disturbances, the predator/prey/competitor/food "terrain", physical constraints, etc.). Another important question is the degree of richness that is required in a real-time 3D perspective of the local environment in order to enable effective control. Recent research has provided increased knowledge of some of the specialized intelligent capabilities that different species of birds, particularly, may use to operate in dense forests at high speeds and other complex environments. This type of biological inspiration would likely yield new insights toward developing principles of perception-based control to enable an autonomous air system to handle the complex physical reality of its immediate vicinity.

Objective: To develop new principles and methodologies for perception-based control of autonomous air systems around complex, unknown, and unstructured terrain based on comparative studies of flying animals, control theory, and computational intelligence. Approaches should emphasize a control theoretic framework and include formulation and utilization of behavioral, cognitive, and/or neuroscience models. The research should include both appropriate experimentation and analytic results under realistic assumptions that show the system will respond in a safe way.

Research Concentration Areas: This topic requires collaboration among the fields of biology, control theory, computer vision/perception, cognitive psychology, computational intelligence, sensors, neuroscience, aeromechanics, and aerodynamics. Research focus areas include: Formulating new control theoretic approaches that can incorporate non-traditional perception techniques as inputs, Performing comparative studies of relevant solutions in nature and exploring the utility of the emerging principles and biological models for perception-based control of engineered systems, Determining the minimum amount of perception/understanding that is required for effective control around complex terrain, and Developing analytic approaches to prove safety that are applicable to complex computational intelligence perception and world modeling algorithms when used within a time-critical control loop.

Impact: This MURI will develop the underlying principles and methodologies that will enable autonomous air systems to operate in complex terrains in close proximity to humans and manned systems. This topic will support casualty evacuation and cargo transport using autonomous systems, which is an important priority for naval forces. It will also support ISR and Search and Rescue missions in complex terrain environments such as under the forest canopy and other future autonomous missions.

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ONR FY2010 MURI TOPIC # 9

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DYNAMICAL SYSTEMS THEORY IN 4D GEOPHYSICAL FLUID DYNAMICS

Background:
In the last ten years, the geometrical theory of nonlinear dynamical systems has been successful in describing certain low-dimensional phenomena in geophysical fluids, such as the Lagrangian transport of fluid particles within fronts, jets or waves. This has led to a deeper understanding of various issues such as the lateral mixing in the ocean and the dispersion of particles and contaminants in the atmosphere. However, much of the theory involved in applying dynamical system techniques to geophysical flows has been performed only for aperiodic flows in two-dimensions. Many of the important flow structures in the ocean and atmosphere are three-dimensional and time-varying. This necessitates the development of new theoretical and computational techniques to describe and understand the higher-dimensional structures that impact the vehicles, sensors, and systems that operate in these environments. Research into the extension of non-linear dynamical systems theory to more complex structures in the ocean and atmosphere will provide insight into many different areas of study: bifurcating flows, convective structures, mixing processes, boundary layer exchanges, and tidal circulations. Through better understanding of these phenomena, the forecasts made using sophisticated, high-resolution numerical models of the environment could be made more useful, and the fidelity of these simulations could be improved, for example through better assimilation of Lagrangian data. More abstract examples of the utility of higher-order non-linear dynamical systems theory include better understanding of the behavior of geophysical fluid variability in phase space, with applications to chaos and predictability.

Objective:
To develop new methods to extend dynamical systems theory into higher dimensions for use in identifying and characterizing four-dimensional structures present in geophysical fluids and explore how these structures evolve over time. Likely activities include: theoretical mathematical development to improve dynamic trajectory analysis in four dimensions, predictive modeling of currents in high-resolution ocean or atmospheric models, and analysis of the impact of the identified structures on physical processes like transport or mixing. Potentially, in-water experiments with drifters, UUVs, floats, or gliders might be included to test theories and new knowledge in realistic geophysical environments.

Research Concentration Areas:
Areas of interest include, but are not limited to (1) an extension of dynamical systems theory to characterize time-varying ocean currents in three dimensions; (2) use of trajectory analysis and Lyapunov exponents to discover pathways and patterns of particle drift; (3) consideration of the use of dynamical systems theory for Lagrangian data assimilation. Additional areas that may be relevant include (1) the incorporation of subgridscale dispersion in model velocity estimates; (2) methods to deal with probabilistic velocity predictions; and (3) consideration of other variables in the ocean environment, such as buoyancy, that may impact the structure of stable and unstable manifolds when dynamical systems theory is applied to complex ocean features and processes.

Impacts:
A better understanding of dynamical flow structures present in the environment would be of use in any application where platforms, sensors, or systems are impacted by these flows. Persistent monitoring missions using UUVs and gliders in the ocean for ASW, NSW and ISR could exploit

these features to reducing the energy needed for propulsion, enabling longer duration missions.

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ONR FY2010 MURI TOPIC # 10

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Hyperspectral, Radar and EO/IR Signatures in the Littorals

Background: The interaction of electromagnetic radiation with water, bubbles and sediment particles in littoral and riverine environments is poorly understood, despite huge investments in airborne and satellite platforms and sensors to exploit phenomenological signatures. Although many sensor signatures have been studied in depth, for example, the use of synthetic aperture radar to sense ocean wave phenomena, many other littoral environmental signatures are not well understood. New developments in data-assimilative modeling suggest significant additional advances will be gained from studies of the signatures of water surface and water column phenomena. Such advances should be further enhanced by fusing information extracted from multiple sensing modalities. For example, high-resolution hyperspectral imagery might be combined with waveform-resolving LIDAR observations to allow unambiguous distinction between the true bottom and sediments suspended in the water column - thus providing not only water depth but water clarity as well. Oil spills are clearly visible in SAR images, but the optical properties of surfactants have not been fused into oil spill products, for example. As a final example, tracking the motion of features visible on the surface of rivers and tidal flows appears to provide a viable means of estimating current speeds in some environments, but a lack of knowledge of the operative signature physics prevents *a priori* prediction of performance in new environments. Newly developed ocean and river models are now capable of assimilating data from multiple sensors, and leveraging this capability for a range of DoD applications awaits only a fundamental understanding of signature physics.

Objectives: (1) Investigate using two or more remote sensing modalities the fundamental physics of signatures of shorelines, waves and currents in littoral and riverine environments in which sediment, bubbles, biota and/or chemicals are suspended in the water column or present at the water surface. (2) Develop approaches for multi-source sensor field assimilation and fusion where a new understanding of the signal interactions with the environment is used to improve environmental parameter estimation.

Research Concentration Areas: This MURI requires multidisciplinary collaborative investigations that will involve experts in remote sensing phenomenologies and experts in environmental field measurements and data-assimilative modeling.

Impact: New understanding of signature physics will enhance significantly the ability to observe and predict the environment with greater fidelity, and lead to technologies and techniques to improve mine countermeasure and expeditionary operations in littoral and riverine environments. Specifically, these capabilities include: the determination of nearshore, coastal and riverine bathymetry; currents, sediment transport and water clarity; detection of bottom characteristics and objects in shallow water; the ability to detect surface and near-surface drifting objects, nets and targets as well as to track vessels on the surface or below it; and detecting and tracing water-borne surfactants. New knowledge from the MURI will motivate the use of small, inexpensive sensors on autonomous aerial platforms to close a number of critical gaps in expeditionary and mine warfare capabilities as well as civilian applications.

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AFOSR FY2010 MURI TOPIC # 11

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Novel Catalytic Mechanisms for the Chemical Reduction of Carbon Dioxide to Energy-Dense Liquids

Background: While many ground-based transport systems may eventually be converted to run on electricity, air vehicles will most likely rely on energy-dense liquid fuels as the primary means to store energy for propulsion for the foreseeable future. Thus, it will be critical to develop and maintain secure, scalable, and sustainable sources of such storable liquid fuels. A desirable situation would be to use a fuel whose production and use do not result in a net increase in atmospheric carbon dioxide; that is, a carbon-neutral fuel. One way to achieve this goal is to produce the fuel using CO_2 as a feedstock with the energy required to chemically reduce the CO_2 to multicarbon-containing hydrocarbons coming from a renewable source of energy such as sunlight. Nature has created such a process in plants, however, the natural photosynthetic system has not been harnessed to affordably make the type and quantity of fuels needed for current and expected aerospace needs. In order to develop a complete and balanced non-biological process to produce liquid fuels from CO_2 and sunlight, a multidisciplinary approach will be necessary to understand the fundamental processes involved, and to understand how they interact with one another in an integrated system. For example, a complete system might need to efficiently absorb and utilize solar energy to produce electrons, transfer those electrons and use them to help chemically reduce CO_2, carry out catalytic reactions to produce hydrocarbons, have an efficient process at an anode to oxidize water, and separate desired products. A strong, multidisciplinary, basic research program is needed to develop the underlying science required to reach this challenging goal. Areas of expertise that can contribute to solving this important challenge include chemistry, physics, materials science, chemical engineering, nanoscience, and computational simulation and modeling.

Objective: The object of this effort is to establish a fundamental understanding of the pathways and molecular mechanisms involved in producing multiple-carbon liquid fuels from CO_2. The understanding will help develop catalysts and systems for the efficient electrochemical or photoelectrochemical multiple-electron reduction of CO_2 and the production of energy-dense multicarbon hydrocarbon liquid fuels. We also seek to develop modeling capabilities of important fundamental processes involved in CO_2 reduction, such as proton-coupled electron transfer. The underlying science needed to develop secure and sustainable pathways for producing carbon-neutral, energy-dense liquid fuels for aerospace transport needs will be established. Non-biological approaches that use carbon dioxide and solar energy as feedstocks are preferred.

Research Concentration Areas: Areas of interest include: 1) Developing efficient processes and high turnover catalysts for the efficient reduction CO_2 to produce energy-dense fuels containing carbon-carbon bonds; 2) Identifying and understanding the molecular mechanisms of the processes of CO_2 reduction and carbon-carbon bond formation; 3) Identifying appropriate electrode materials that make efficient use of the solar spectrum to produce electrons needed for CO_2 reduction and understanding the detailed mechanisms of production, transport and donation of electrons; 4) Understanding and developing a predictive modeling capability for the multiple-electron and multiple-proton processes needed to avoid pathways with high activation energies in CO_2; 5) Developing novel material designs for electrochemical systems to convert CO_2 to chemical fuels.

Impact: The production of a secure, scalable, and sustainable source of storable liquid fuels for aerospace applications is one of the most critical needs to permit continued use of aerospace assets in the future. Existing energy sources fail to meet at least one of the above criteria, threatening future aerospace operations. A new paradigm of fuel production is needed as a cornerstone for future national and environmental security.

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AFOSR FY2010 MURI TOPIC # 12

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Third Order Nonlinear Optical Organics

Background: Organic nonlinear optical (NLO) materials can potentially be used in many military applications. While second order (for high frequency electrical field modulation) and third order imaginary (for nonlinear absorption) NLO materials have made significant advances in recent years, advances in the real component of third order nonlinearity susceptibility ($Re\chi^{(3)}$) and understanding on how to control the ratio of ($Im\chi^{(3)}$/ $Re\chi^{(3)}$) are still lacking. These materials are limited by insufficient third order nonlinearity and large nonlinear absorption loss. Improving the real component of the third order nonlinearity with minimal imaginary component will lead to a new generation of molecular photonic materials with large high-speed index changes (in f-sec), and will enable new fast response photonic applications. Recent advances in spectroscopic techniques and theory have greatly clarified the understanding of how molecular structural parameters (symmetry, packing and topology) and electronic states (including excited states) of conjugated molecules influence the third order nonlinearity of organic molecules. A multidisciplinary, closely collaborative effort that includes theoretical modeling, molecular synthesis, spectroscopic analysis and optical nonlinear characterization will bring the necessary advances to provide the materials needed for many military applications.

Objective: To understand the molecular design principles of organic materials to increase third order NLO real component with minimal imaginary component. The research should provide fundamental knowledge on how to satisfy two figures of merit simultaneously in a single material ($W > 1$ and $T < 1$), which characterize the ratios of optical nonlinearity to one-photon and two-photon absorption losses respectively. These two figures of merits are defined as: $W = n_2 I/\alpha_1\lambda$ where n_2 is the nonlinear index, I is the intensity, α_1 is the absorption coefficient and λ is the wavelength, and $T = \alpha_2 \lambda/n_2$ where α_2 is the two-photon absorption coefficient**.**

Research Concentration Areas: (1) Theoretical Modeling: Utilize the latest advances in computational techniques such as time dependent Density Function Theory (DFT) and semi-empirical Hamiltonians, Intermediate Neglect of Differential Overlap (INDO), complemented by highly correlated schemes such as Multi Reference Determinant – Configuration Interaction (MRD-CI) approach or a Coupled Cluster (CC) approach to calculate molecular properties based on specific organic molecular structures. (2) Molecular Design and Synthesis: With the insight gained from theoretical studies and structure-properties intuitions, new molecular structures will be designed and synthesized to test these understandings and probe the validity of the theories. Influence of molecular parameters such as symmetry and material characteristics such as aggregation on nonlinear behavior will be taken into considerations. (3) Spectroscopic Investigation: Excited states energy levels and energy transfer dynamics between these states will be probed with advanced spectroscopic techniques, such as white-light continuum pump-probe spectroscopy, to provide an understanding of the influence of molecular structure on the electronic energy levels and their interactions, and to validate theoretical predictions. (4) Nonlinear Optical Characterization: Advance techniques, such as degenerate 4-wave mixing and white-light f-sec Z scan will be used to characterize the molecular hyperpolarizability and the real and imaginary third order nonlinear susceptibility of bulk materials.

Impact: The fundamental results from this MURI will lead to development of fast response optical nonlinear materials to impact ultra-high speed optical computing, optical signal processing, robust optical communication links between fast moving mobile platforms, real time target recognition, nonlinear diffraction of coherent light, and aberration correction for optical imaging and many other optical applications.

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AFOSR FY2010 MURI TOPIC # 13

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Fundamental Processes in High-Temperature Gas-Surface Interactions

Background: Rapid global delivery of conventional munitions with pinpoint precision is a critical capability required for countering the potential deployment of weapons of mass destruction. The in-flight aerodynamic shape of such Prompt Global Strike systems determines not only the cross-range of the system but also the terminal accuracy. Unfortunately, accurate prediction of the in-flight surface condition and shape of these systems is currently impossible due to a lack of accurate models for the nonequilibrium gas-surface interaction and material response. To achieve precise vehicle guidance, navigation and control, the time-varying aerodynamic shape of such vehicles must be accurately known throughout the flight trajectory. Significant advances must be made in understanding both the nonequilibrium environment and the fundamental processes of gas-surface interactions which drive in-flight degradation. Such knowledge will allow the characterization and prediction of dynamic system performance. Additionally, the development of *smart ablators* – TPS systems designed to either ablate in a controlled manner or promote beneficial interactions to radically impact system performance – requires the establishment of a robust scientific base of fundamental gas-surface interactions.

Objective: Research addressing this topic will develop the basic knowledge building blocks required for the eventual development of both a predictive capability for the in-flight degraded shape of maneuverable reentry systems and innovative smart ablator thermal protection systems. This effort will characterize and model the fundamental nonequilibrium physics and chemistry in the flow behind a shock wave, within the high-speed boundary layer and in the gas-surface interaction occurring at the surface of the TPS system. Particular emphasis will be placed on defining accurate rate-dependent models for both the distribution of molecular energy between the kinetic and internal modes of the gas in the flowfield and the reactions dominating the gas-surface interaction. In the latter stages of this effort methods for controlling either the flowfield or the surface response via designed gas-surface interactions will be explored.

Research Concentration Areas: Establishment of the essential science base for the prediction of in-flight surface degradation and the development of smart ablator capabilities will require a multidisciplinary effort integrating numerical and experimental contributions from the areas of aerothermodynamics, nonequilibrium gas chemistry and high-temperature materials. Areas of emphasis include, but will not be limited to: 1) Development of rate-dependent models for the distribution of kinetic and internal energy within the gas, 2) Characterization and modeling of the dynamic reactions dominating gas-surface interactions, 3) Exploration of control of the flowfield or surface response via designed interactions between surface reactions and the energy distribution or physical features of the boundary layer, 4) Development and utilization of next-generation diagnostic and numerical methods enabling to this effort.

Impact: Establishment of the essential science base required to model nonequilibrium gas-surface interactions, predict the resultant material response and impact on the flowfield, and potentially control the ablation of TPS systems will profoundly advance the design and performance of a broad spectrum of planned hypersonic capabilities including Prompt Global Strike, Space Access and Planetary Reentry systems. The multidisciplinary communication and collaboration required to achieve the objectives identified in this topic should foster significant interactions between large segments of the associated scientific disciplines. As a result, national scientific capabilities to address similar complex basic research issues will be bolstered.

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AFOSR FY2010 MURI TOPIC # 14

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Propagation of Ultrashort Laser Pulses through Transparent Media

Background: Less than 12 years ago experiments in Europe reported that IR laser pulses of ultrashort duration (<100femtoseconds) but with substantial power (exceeding 10^{12}W) would propagate through clear air for kilometers with significantly reduced diffraction. Within the pulse could be found hundreds of filaments which individually appeared and disappeared. Later experiments demonstrated that such a collection of filaments would pass through clouds with relative ease, raising speculation that these pulses might provide the DOD with a ladar usable on a cloudy day. Each filament produces a plasma channel which possibly can serve as a waveguide for electromagnetic fields exploitable by the DOD as a radar system component.

Objective: The purpose of this MURI is to pursue basic experimental and theoretical research to explain and simulate as completely as possible such attributes and provide first-principles guidance to effectively exploit this exciting phenomenon. Specific issues that should be addressed include:

1) A clearer understanding of the relation between combinations of initial conditions (frequency, duration, pulse diameter, chirp, etc) and ultimate propagation distance. For example, experiments involving initial frequencies in the UV and having picosecond duration have been undertaken with modest distance results.
2) A clearer understanding of the dynamics of multifilaments within a pulse, including a generalization of the pairwise attraction or repulsion known to occur under certain conditions. Likewise, further basic research is merited to pursue understanding of coupling between two/multiple intersecting beams leading to amplification of one.
3) A clearer understanding of the effective means for extending the RF-waveguide in space and time. The results of a recent Canadian experiment invite innovative alternatives.
4) A clearer understanding of the role beam shaping plays in the subsequent behavior of the pulse. Recent European reports suggest some interesting strategies, while efforts to duplicate the linear optics phenomena of the bending/deflection exhibited by Airy beams in this nonlinear realm also merit further attention.
5) A clearer understanding of what mathematical models are suitable for the replication and prediction of experiments. A notable advance in this area replaces the 2nd order nonlinear Schrodinger partial differential equation with a pseudo differential nonlinear Schrodinger equation in order to correctly replicate the super-continuum production of wavelengths. This encouraging development needs to be accompanied by a suitably detailed description (Drude-like model) of the propagation medium.

Research Concentration Areas: The proposed work focuses on the mathematics and modeling (coupled systems of nonlinear partial differential equations) necessary to describe the process of laser-induced plasma formation and electromagnetic field coupling to a plasma filament, with verification of the model with existing experimental results. Research expertise in mathematics, physics, radiation sciences, materials sciences, and optical engineering may be relevant to formulate, analyze, and validate new ideas in laser-induced filamentation science.

Impact: Most important is the scientific understanding of laser-induced filaments and their propagation through transparent media which this MURI would support. It would also provide the opportunity for a greater domestic capability in this exciting area.

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AFOSR FY2010 MURI TOPIC # 15

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Superconducting Semiconductors

Background: Superconducting semiconductors, first discovered in GeTe and $SrTiO_3$ in the 1960s, merit a second look due to breakthroughs in materials synthesis and the potential for new applications in electronics. $SrTiO_3$, one of the first "super semis" ever discovered, was recognized by Bednorz and Muller as an inspiration for their discovery of high-Tc cuprate superconductors. Now, new material synthesis techniques for non-equilibrium doping of both Si and diamond have been developed. Electrical gating of the superconductor-insulator quantum phase transition at the interface between oxide semiconductors has been demonstrated. Nonvolatile control over the electronic ground state in this system has opened new avenues for the intermingling of superconducting, spintronic, optical and electronic properties at the nanoscale. Single-ion control of electronic and spin degrees of freedom in diamond, coupled with superconducting electronics, could form the basis for novel classical and quantum information processing. Motivation for this topic comes from the discovery of superconductivity in highly-doped Si and diamond, quantum control of defects in diamond vacancy centers, electrical control of 2-D superconductivity in $LaAlO_3/SrTiO_3$ heterostructures, and nanoscale control of the metal-insulator transition.

Objective: This topic seeks to establish the feasibility of hybrid electronic architectures that are part superconductor, and capable of both traditional and quantum information processing, storage or sensing capabilities. Devices and architectures that make use of high-speed electrical and/or optical modulation or gating of the superconductor/insulator transition are sought, with the potential for high-density integration using extensions of existing semiconductor fabrication pathways. The goal is to create new information storage and processing media that would be faster, smaller and less dissipative than for current semiconductor-based electronics.

Research Concentration Areas: Collaborations between physicists, materials scientists, chemists and quantum information scientists will be required. Materials of interest include those for which recent progress has been made (e.g., Si, diamond, $SrTiO_3$), but exploratory work in other semiconducting materials, even those not yet demonstrated to be superconducting, will be considered, provided that the consequences of success are identified. Researchers should attempt to establish and exploit functional links between the superconducting order parameter and individual quantum degrees of freedom (e.g., spin, photonic, charge, orbital, and nuclear). Demonstrations should consider integration of superconducting and semiconducting behavior at length scales comparable to or below the coherence length and approaching the 2-D limit for which single quantum channels are involved. Also of interest is the development of configurations capable of quantum simulation of other fermion-based condensed matter systems (e.g., correlated electron systems or other superconductors).

Impact: This topic could lead to the development of multifunctional high-speed electronics that is both lightweight and capable of operating with extremely low dissipation. Development of new, efficient means of transferring information over chip-scale dimensions will overcome a bottleneck and yield a new generation of information processors, sensors and electronic components essential for DOD and industrial applications. Early architectures may require cooling, but success may encourage further development of higher-temperature and even room-temperature applications. Quantum simulation may accelerate development of new materials, leading to new electronics applications, including those capable of aiding in complex designs.

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AFOSR FY2010 MURI TOPIC # 16

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Human-Machine Adversarial Networks

Background: In traditional game theory, the two players were assumed to have full control over their own actions, and there were only overly simplistic models of the observation process. These assumptions are not consistent with post-modern conflict. In reality, we have adversaries that are instantiated as networked entities. These networks are comprised of nodes which may be human or machine. In the latter case, the node might be a communication hub, an internet server, a sensor or an autonomous vehicle. In some types of conflicts, the nodes might even be news-disseminating websites. The nodes are linked by communications, and the actions of the nodes are constrained by the information reaching them. The information transiting over the network may consist of observations, estimates, commands, etc. If there exists a central commander, it makes decisions based on the information reaching it. The resulting commands may or may not reach the intended recipients, and may be at a higher level in the hierarchy than individual node actions. Moreover, the state of the entire system consists of both the physical state and the information state. The physical state consists of well-known quantities such as position, velocity, health and so on. Many of these are values which are traditionally considered in game theory. However, we see that we must also describe the network state in terms of which nodes are in communication with which other nodes, and perhaps the quality of those connections. We must also describe the information available at each node, and ideally, also the protocols describing what types of information are passed. The full state is clearly a much more complex object than that considered in traditional approaches to game theory. The general question of interest to us is how to best achieve one's goals. Obviously, removal of particular communication links could prove highly advantageous. However, this insight merely gives a sense of the problem, much as the insight that removal of an opponent's pieces from a chessboard should prove useful. There is much more to be gained through rigorous analysis. Further, in a more advanced form, one could even consider the application of cognitive disruption – the insertion of false information into the opponent's information state, rather than the mere prevention of information transference.

Objective: Develop the fundamental tools which will, in theory, allow one to solve games between networked entities. One component would be the development of mathematical models of such games. Secondly, one would like to develop theory that would allow one to solve such problems on a small scale, and approximations that would allow larger-scale near-optimal problem solution. The inclusion of both physical and informational actions, possibly including cyber and cognitive play, would be necessary. Repeated testing via gaming with actual human-machine networks and a simulated physical environment will validate the resulting benefits.

Research Concentration Areas: Areas of interest include but are not limited to: i) New Game Theory (from Mathematics and Economics) directed toward problems of networked players that both observe the state and control their actions through the network; ii) Cyber-Security for consideration of non-physical network disruption; iii) Methods of Semantic Attack and Cognitive Disruption as well as the theory for incorporation of such into solvable games.

Impact: Improvements in models, where important structure is added, typically result in greatly improved behavior. Similarly, we can expect that in future operations, these new technologies will allow us to achieve the desired goals at hugely reduced cost (in life and equipment) through proper consideration of the problems as games between networked opponents.

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AFOSR FY2010 MURI TOPIC # 17

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Biologically-Engineering of Adherent / Spectroscopically Interrogated Microstructures

Background: Nature provides a number of instances where microparticle structures, with intricate nanoscale features specifically tailored for effective adherence or entanglement to/with a variety of surfaces, were utilized for dispersal. For example, pollens, diatoms, and certain seed structures are microscale or larger particles containing nanostructured protuberances (reminiscent of gecko feet and fish hooks) for effective attachment to a variety of surfaces. An understanding of how to tailor cells to generate micro scale structures and how these structures interact with surfaces is needed. In addition, such biologically-derived structures are not functionalized to allow spectroscopic interrogation and detection. Research to enable new unique materials designs and functionalization strategies are needed for remote overt or covert detection. Since these materials are robust, they tend to be insoluble in a number of solvents, complicating characterization. New research methodologies for handling and analyzing these unique materials are necessary. In addition, new synthetic materials and interrogation strategies are needed to enable remote stimulation with optical responses for subsequent remote detection within confined wavelength and temporal ranges. The basic research to couple biologically-tuned nanostructured adherent surfaces with synthetic chemistries for remote and tailored stimulation/detection would provide an unprecedented new scientific understanding and the tools for both bio-engineering and remote interrogation/detection. Innovative, reliable, and prolonged micro-tagging will require the investigation of novel mechanisms of dispersal such as microscale particles with robust structures tailored for adherence and with chemistries tailored for remote detection to be effective; hence the need for this scientific study.

Objective: Study the mechanism of directed assembly of complex geometric structures. Develop an understanding of how these biologically-tailored nanostructured microparticles are formed and how to alter and direct the assembly or new geometries and materials systems. Develop innovative new methods to modify organisms to tailor the formation of these biologically-tailored nanostructured microparticles and to understand the chemistry behind their composition, morphology, and modes of attachment. Perform research of new detection methodologies that are extremely sensitive and can differentiate between the bio-engineered particles and their naturally occurring counterparts. This will potentially require the use of tailored biochromophores and nanomaterials, necessitating the study of these tailored materials and understanding the chemistries to either coupling these materials to the microparticles or coexpression of microparticle and chromophore. In addition, the lifetime and intensity mechanisms of the native chromophore and the effects of binding to substrates will need to be understood. Future synthesis of optically interrogated natural systems utilizing these materials will require either understanding the mimicking of these particles or use the genetic tailoring ability create structural shapes.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) discovery of the structures and materials that effectively adhere to, or entangle with, a variety of surfaces; (2) synthesis of nanotailored and chemically modified bio-derived particles; (3) isolation, sequence determination, expression, and structure determination of robust biochromophores; (4) novel remote detection schemes to activate and detect nanotailored microparticles; (5) modeling the dispersion, adherence, lifetime, and detection of taggant materials; and (6) synthesis of dynamic bio-derived and bioinspired materials and structures.

Impact: New tailored bio-derived materials with tunable complex geometric structures including adhesive/entanglement functionalities. Under desired detection/activation conditions allow for discrete remote detection and spectral interrogation at near zero concentrations. These new biomaterials will have tunable lifetimes through the use of bio-labile materials. The resulting knowledge will enable directed assembly of new complex geometries to track adversary movements, monitoring cleared areas, and tagging urban targets. This new science will have direct applicability to both military and civilian sectors.

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AFOSR FY2010 MURI TOPIC # 18

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Control of Information Collection and Fusion

Background: Most of modern control science addresses situations in which the control objectives are readily quantifiable, state dynamics are well modeled, and the effects of control actions on the state are predictable. With the emergence of sensing concepts that capitalize upon the rapidly increasing availability of controllable degrees of freedom, ranging from sensor operating mode to physical control of the platforms carrying the sensors, there is a need for new control science for information collection. Achieving this vision will entail several significant challenges beyond the scope of the current state of knowledge. Innovative means of quantifying objectives and states that are not physical, but informational (i.e., “situational awareness”) or jointly physical-informational, will be required. Mathematical models that capture the evolution of such states and predict how they are affected by control actions will be essential to achieve optimal feedback strategies for information collection. Unified representations capable of simultaneously accommodating and supporting inference on data from disparate sources, including both quantitative “hard” sensor data and less quantitative “soft” information, such as expert opinion, will be necessary to define control laws that can efficiently task all available information sources to attain and maintain desired states of information.

Objective: This MURI will forge a rigorous new perspective on the joint control of multiple information sources of disparate types to simultaneously achieve quantified informational and physical objectives. Ideas from control theory, as well as from the regimes of signal and information theory, computational sciences, and optimization are anticipated to bear on this objective. New foundational methodology for information collection and fusion that exercises rigorous feedback control over information collection assets, simultaneously managing informational and physical aspects of their states, is expected to arise from this perspective. Characterization of the methodology developed in terms of performance bounds, scalability, and robustness is an explicit goal of the MURI.

Research Concentration Areas: (1) Representations: Develop unified mathematical representations for sensor, control, and auxiliary data that are capable of incorporating multiple scales of resolution and sensitivity, are compatible with layered sensing and hierarchical control schemes, and admit rigorous means of computational manipulation to include inference with quantified uncertainty; (2) Joint Physical-Information State: Formulate descriptors suitable for simultaneously capturing the physical state of the information gathering system (e.g., dynamic states of the platforms) and the state of information (e.g., the degree of situational awareness achieved through past information-gathering actions). This should include quantification of the desired set of information and physical states to be achieved/maintained through control of the information gathering system and should also support constraints limiting state transitions; (3) Control-Information Linkage: Establish means to predictably and robustly link control actions to information state effects in order to support feedback strategies that enable simultaneous control of physical states and information states.

Impact: The primary impact sought by this Topic is creation of control science for the age of ubiquitous data, spanning current boundaries of control theory, information theory, sensing and signal processing. A broad spectrum of application impact is expected. In the context of current and future air operations, diverse (semi-)autonomous assets with varying capabilities and taskable sensing modalities present many controllable degrees of freedom that simultaneously affect informational and physical objectives. This Task will enable optimization of multi-mission effectiveness in complex, dynamic, and uncertain environments. Impact is anticipated in numerous other DoD and civilian applications that involve fusion of multi-modal sensor information in the presence of dynamical models, side information, and uncertainty to achieve desired high-level awareness. These include Space Protection and Awareness

(SPA) and Structural Health Monitoring (SHM) for air, space, and maritime structures.

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AFOSR FY2010 MURI TOPIC # 19

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Stable Metrics for Global Inference in Social Networks to Predict Collective Behavior

Background: Recently, several strategies have been developed to globally predict group behavior and performance in social networks. Approaches include web and graph based strategies, ontological and sociological models, and demographic and data mining methods. The problem with these methods is that they do not always have objective and reliable underlying metrics of performance on which stable inference can be performed. An understanding of the latent structure of the complex web of social-cultural variables and the ability to express this in a computational framework will contribute to the elucidation of invariant predictive qualities.

Objective: The objective of this MURI solicitation is to enable rigorous probabilistic assessment of collective behavior by starting with stable metrics of both individual and collective preference and behavior and, thereby, infer fundamental properties of group behavior from these statistics. We would like to encourage methods to derive metrics that are based on stable underlying statistical quantities through the use of techniques such as geometric analysis of large corpora of digital traces of human activity, such as multi-media communications, social media, digital images and video, and other sources of relevant social interaction data. At this level computational methods derived from discrete geometric, probability, and decision theory can be applied to the data sets and analyzed for invariant properties. These properties can be assessed in terms of such quantities as topological properties, probability distances, and divergences that geometrically separate one class of behavior from another. These properties could be referenced in terms of group rule sets in professional and legal behavior, academic referencing and citation, online social networks, news and media preferences, economic partnerships, and cultural and religious group identification. More globally, these approaches should inform theories of collective behavior. These rules can then be posed in the context of classical ontological or graphical based models of social behavior.

Research Concentration Areas: Research concentration areas may include, but are not limited to, probabilistic and geometric analysis of data sources such as (1) text and character information, (2) voice and video sources, (3) gesture and symbolic assessments, (4) methods to characterize group policies, and (5) global methods of analysis of group cohesiveness and future behavior. From these areas we wish to infer stable properties with correspondences to the tendency of group, societal, or cultural activities toward certain behavior, such as coexistence, tolerance, violence, and conflict.

Impact: The impact of this program will be to be able to perform stable estimation of group behavior in a number of contexts. Applications for these methods include alternative course of action analysis and prediction. This project will enable consistent assessment of global behavior of a group for a wide variety of DOD scenarios.

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AFOSR FY2010 MURI TOPIC # 20

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Solid State Cooling

Background: Over the last several years, significant advances have been made in increasing the efficiency of solid state cooling. Advances have occurred in: laser cooling, quantum cooling, nanostructured graphene, carbon nano-tubes and thermoelectric (TE) Peltier cooling. With regard to Peltier cooling, the fundamental challenge is circumventing the Wiedemann-Franz law, which states that most materials having a high electrical conductivity, δ, also have a high thermal conductivity, κ. The latter parameter is in the denominator of the figure of merit, $ZT = S^2 T \delta/\kappa$, and severely limits the effectiveness of thermoelectrics. In addition, methods that enhance the electrical conductivity usually decrease S, the Seebeck coefficient, which also contributes to a low performing thermoelectric. However, at the AFRL/RV 2009 workshop, which reviewed the extensive progress already made in Peltier cooling, presentations by prominent physicists, theorists, chemists, materials scientists and nano-scientists, showed that these obstacles can be overcome by synergistic efforts among the several disciplines. Speakers from Max Planck Institute at Dresden, Walter Schottky Institute at Munich, the University of Pisa, and 10 U. S. Universities and Institutions participated. For example, an increase of 2 orders of magnitude in the Seebeck coefficient was reported for the alloy, $FeSb_2$, due to hybridization of its 3d and 5p electrons, which occurs without reduction of the electrical conductivity. Other researchers reported reductions of two orders of magnitude in κ for thermoelectrics at room temperature through advances in metamaterials, quantum confinement and nanostructures.

Objectives: Carry out a program of coordinated research involving computer modeling, physics, chemistry, materials science, metamaterials, and nanostructures that further enhance Peltier cooling properties. Find other thermoelectric alloys possessing superior solid-state cooling capabilities whose high Seebeck coefficient does not reduce the electrical conductivity. Make use of Type II Misaligned Superlattices, such as in $InAs/GaSb_2$, to transition semimetals to semiconductors, which produces the narrow band gap required for Peltier cooling. Make a significant reduction in the thermal conductivity at cryogenic temperatures by use of nano-structured composites, metamaterials and quantum confinement.

Research Concentration Areas: Cryocooling using thermoelectrics requires a trade-off between material parameters that can only be achieved by an intensive, synergistic research effort. Additional work is required to exploit recent advances in Type II Superlattices, whose misaligned band gaps can be manipulated and doped to produce optimum cooling at several different temperatures. Further research is needed in quantum confinement, combined with metamaterials and nanostructures, to decrease the thermal conductivity by 2 orders of magnitude at cryogenic temperatures without adversely affecting the electrical conductivity. New materials are sought with hybridized 3d and 5p electrons, i.e., alloys of Fe/Co/Ni alloyed with elements in row 4 of the periodic table to provide thermoelectrics with a high density of states. Approaches that increase the Seebeck electron-phonon coupling are equally important.

Impact: Small, 500kg surveillance satellites with cooling to 10K can only be realized by on-board solid-state sensors that allow them to operate over a wider range from x-ray wavelengths to the very far infrared. Thermoelectrics, for example, would revolutionize the architecture of surveillance satellites from weight and cost considerations. Solid-state cooling also can dramatically affect DoD’s terrestrial IR sensor programs, and NASA’s and DoE’s space needs. Further advances in solid-state cooling will enable x-ray sensors and extremely sensitive bolometers for space situation awareness; enhance the reliability of electronic components; directly cool IR diode lasers; and increase the sensitivity and spectral range of UAV sensors.

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ARMY FY2010 MURI TOPIC # 21

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Neuronal Behavior in Primary Blast

Background: Explosive device detonation begins a complex event which includes the propagation of a blast wave in air, the interaction of the incident wave with any protective system and the body, and the transmission of strong stress waves into the tissues. Modern high speed projectile injuries also will have a component of blast injury. Soft tissue response to the dynamic loading conditions produced by these stress waves as well as the resulting injury mechanisms is poorly understood. Theories on the cause of primary blast brain injury include a combination of effects including cavitation, chemical toxicity, heat, ischemia, light, and electromagnetic forces. Proposed cell and structure-level brain injury mechanisms due to common impacts may include diffuse axonal injury attributed to shearing and stretching of axons and small vessels, concussion, hematoma, and cerebral contusion, but do not address coupled effects or higher strain rates, and do not address mild TBI or those that become apparent after longer time periods (weeks to months). Current understanding of the effects of primary blast injury on brain tissue has arisen from imaging and neuropsychology. Imaging methods covering detectable trauma or damage, through finer and finer anatomical resolutions, remain constrained by signal to noise limits, e.g. Diffusion Tensor Imaging. Concurrently, the psychological evaluation of cognitive deficits remains confounded by human variability. Both areas are usually related only to the initial easily quantified sharp transient pressure wave of a blast event. Functional correlates of detected anatomical and/or histological changes and measurements of the actual physiological effects of blast events vs. the complete mechanical loading histories, including resonance and reflection effects are missing. Assuming that all clinical symptoms of mTBI and PTSD are based on synaptic alterations in the brain, research on synaptic function itself in response to transient, low level, possibly repeated pressure events is sparse. Developing data on injury maps/evolution will provide a new basis for armor design, founded on the manipulation of input blast waveform to minimize the resulting synaptic damage.

Objective: To create a fundamental predictive understanding of the link between high-rate loading profiles and tissue response mechanisms by developing a quantitative multi-scale mechanistic model of neuronal population function loss and recovery versus the complete loading history from single and repetitive blast-like exposures.

Research Concentration Areas: Research should investigate the transition between affected and unaffected regions; thresholds; local biological processes, including intracellular as well as intercellular communication, on time scales of seconds to weeks; healing and tissue remodeling, and PNS function (multisensory, motor, reflexive). These studies must be coupled with investigations into the physics of tissue dynamics (stress, strain, etc.) as a function of the entire input wave. A robust methodology for defining, generating and controlling experimental input waveforms is expected. A verifiable means of interrogating and quantifying via analytic metrics subsequent localized pressure, and deformation history details is to be demonstrated. The effect scales should range from the single synapse, e.g. squid giant synapse, through MEA cell cultures, scaffolded 3D cell cultures, organotypic brain slices to chronic in vivo recording in animal models. Exclusions include considerations of fragments, rounds, penetrating injury, region-specific problems e.g. torso/head (CNS, air-filled or fluid-filled voids, organs), external ecology (skin microbial symbiotes, etc.), and long term effects (more than two weeks).

Impact: This research may provide a basis for shifting armor design efforts from defeating the threat based on material deformation, damage, and rupture, to mitigating the effects based on preserving the protected tissue biology, with civilian uses in automotive and sports trauma.
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Identifying and Extracting the Mathematical Signatures of Prokaryotic Activity in DNA; Developing a Theoretical Foundation for Predicting DNA Stability

Background: It has been recently demonstrated that genomic signatures in mitochondrial DNA encode information that reveals where your mitochondrial ancestors were 5 to 20 thousand years ago. This is useful if you are an anthropologist but not so useful for DoD. It would however be very informative to know where an organism was in the last six months.

DNA mutates in prokaryotes at a rate of approximately 1 in 300 nucleotides per generation, and generations can be as short as ten minutes. Nucleotides in genes are organized into groups of three (codons) and each codon encodes one amino acid or a start or stop signal. Because there are 64 (4^3) codons but only 20 naturally occurring amino acids there is in most cases more than one way to encode the amino acid. Most informational redundancy is encoded in the third nucleotide, and this is known as the wobble base; nucleotide substitutions that change the DNA sequence without changing the protein sequence are known as "silent" mutations. These "silent" mutations are however not functionally equivalent; different species have different codon bias and this has a significant effect on translational efficiency. Amino acids are assembled into two dimensional strings which then form three dimensional structures (proteins), which are then able to transport molecules, catalyze reactions, form pores or membranes, replicate or repair DNA or organelles or proteins, or do any of the other of thousands of functions that must be performed by proteins for the organism to survive and prosper. Changes in some amino acids will lead to an increase, decrease, or loss of protein function, while others will have no effect, or will only have an effect under specific circumstances. It also matters what the mutation is; a specific nucleotide that is normally encoded by an A for example, might increase protein activity if changed to a C, decrease protein activity if changed to a G, and result in no protein activity if changed to a T.

The result of all of this is that while each nucleotide in the genome can mutate, the frequency of inherited mutations varies depending on both intracellular and extracellular factors, including DNA context, protein binding sites, transcription rates, protein expression levels, as well as context dependent selection pressures. If these mutation patterns were untangled, the resulting information could reveal where the organism has been and what it has been doing.

Objective: The objective of this MURI is to develop an experimental and theoretical foundation for predicting DNA stability and extracting information encoded patterns of inherited mutations in prokaryotic DNA to reveal an organism's recent history and activity.

Research Concentration Areas: Suggested research areas include but are not limited to: 1) large scale genetic analysis to characterize genetic and genomic instability in an appropriate model prokaryote under informative physiological conditions, 2) develop new large-scale numerical matching or optimization techniques to analyze these types of highly complex data at a systems biology level and to extract the genetic signatures, 3) systems biology and network modeling to develop a theoretical basis that will enable the identification and prediction of mutation rates in various genetic components, and 4) model validation by testing the predictions in other prokaryotic species.

Impact: This MURI will enable basic research to develop new mathematical capabilities in stochastic optimization algorithms and a theoretical foundation for identifying and understanding the factors that affect genome stability. The ability to extract information encoded in mutation rates could be used to identify prokaryotic origins; when, where, and how bacteria were grown.

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ARMY FY2010 MURI TOPIC # 23

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Tomography of Social Networks of Asymmetric Adversaries

Background: It is widely recognized that identifying, characterizing and neutralizing the covert social networks that put in place and sustain terrorists/insurgents is vastly more efficient than searching for these people once they are in place and ready for action. Experienced intelligence officers can be quite successful at identifying such networks from human reports, sensor data, cell telephone calls and databases, but intelligence officers are overloaded. For anti-drug, anti-crime and immigration enforcement and for marketing, government agencies and civilian companies already have various computational procedures that aid human experts in automatically identifying social networks. These procedures can produce success in examples but have high false-positive and false-negative rates for covert networks. The limited success of the computational procedures developed so far is due in large part to the fact that the fundamental principles that allow automatic, no-human-in-the-loop identification and characterization of covert social networks based on externally observable information are not yet known. The report *Network Science* (Board on Army Science and Technology, 2005) recommends strongly increased research in network science, including modeling of social networks. The recent explosion in availability of data for social networks is an excellent basis that will allow this research to proceed rapidly.

Objective: Develop quantitative procedures to identify, characterize and display, on the basis of externally observed data generated from passive and/or active procedures, covert social networks of asymmetric adversaries, that is, terrorist/insurgent networks.

Research Concentration Areas (RCAs): Research in mathematics, sociology, cultural anthropology, data mining, learning theory and network theory will be required on the following topics: (1) Develop nonlinear quantitative procedures to infer from externally observed data by automatic, no-human-in-the-loop procedures the existence, topology, leadership, interactions and other characteristics of the type of covert social networks that generate terrorist/insurgent activities. The procedures must be embedded in applicable sociological theory (and not simply be computationally descriptive of sociological phenomena). The information about the networks may be passively observed (e.g., using documents, media, databases, SIGINT, COMINT, physical sensors, etc.) or actively generated by sending physical or informational items into the social network and observing effects thereof. (Active generation of information must not perturb the social network.) The procedures must be computationally feasible (not combinatorially expensive), scalable and “data-tractable” (able to produce accurate results with data no more than are realistically likely to be available). (2) Develop or determine appropriate metrics to measure characteristics of social networks. All metrics must be computationally feasible, mathematically justified and based on known or hypothesized sociological principles. Ad hoc or purely heuristic metrics are insufficient. No/few of the items or parameters in these metrics should require “tweaking”. (3) In the metrics of RCA 2, determine tradeoffs, such as those between how much and/or what kind of data is used as input and accuracy of the social networks computed using these data. (4) Determine limitations of the procedures, including whether the procedures cannot, based on certain amounts or classes of data, identify some types of social networks. (5) Verify and validate the procedures on empirical data. NOTE: Active deception by the social network and prediction and disruption of that network by the Blue Force are too large for this present effort and need not be considered. Deception will, of course, have to be part of the active generation of information (RCA 1) so that the network is not perturbed by knowledge of being under investigation. However, active planting of misleading information (beyond just covert operation) by the social network itself, as important as this topic is, need not be considered.

Impact: This research leads to getting the network before it places active threats in place. Dual civilian uses are in anti-drug, anti-crime, immigration enforcement and marketing.

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ARMY FY2010 MURI TOPIC # 24

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Adaptive Perception and Agile Autonomy in Severe Environments

Background: Autonomous ground vehicles are envisioned to support a wide range of military operations under challenging conditions and in severe environments. Consequently, “high-dynamic” maneuverability is an essential capability for autonomous ground vehicles in military applications, particularly in hostile urban regions with severe environmental conditions. Despite progress, current unmanned ground vehicles are mostly restricted to low-dynamic benign terrain and well-structured environments such as highways. They also require a computationally intensive panoramic understanding of the surroundings to provide sufficient range for high speed maneuvering. The main reason is that existing methods have been mostly based on two critical assumptions: (1) the interactions between the vehicle and the surface terrain can be sufficiently approximated so that motion control can be formulated as a linearized control problem, and (2) the speed of the vehicle is sufficiently slow to allow reactive control. The second assumption also implies decoupling of motion control from perception. Under severe "high-dynamic" conditions, the above assumptions do not hold, and a vehicle's current state simply does not provide sufficient information to allow full control. To cope with this problem, the research community has recognized the need for new methods that instead of “steering” an idealistic non-holonomically constrained vehicle, control the sliding and ballistic motion they might encounter in real-world terrain. These new methods require tight coupling between motion control and perception in which predictions are made, and control actions initiated based on what the future environment is most likely to be. It is believed that predictive control may provide a means for high-speed motion control because it allows for incorporation of both adaptive sensing and the requisite environment understanding required. This research will create the underlying theory required for adaptive perception and agile autonomy in severe environments by building on current “predictive control” techniques (e.g. model-based control), and constructing new mathematical and physical methods that integrate vehicle sensing and control, surface terrain sensing, and non-linear modeling.

Objective: The objective of this MURI effort is to develop an analytical framework and lay a theoretical foundation for adaptive perception and agile autonomous control of unmanned ground vehicles in severe environments and under challenging operational conditions. Of particular interest are accurate, efficient and demonstrable computational procedures to realize this vision.

Research Concentration Areas: A tight integration of perception and intelligent control, which inform each other, is expected for this effort. Areas of interest include, but are not limited to, (1) approaches to the sensing and modeling of surface terrain in a variety of environments. Potential solutions should not solely rely on information from the Global Positioning System or onboard gyroscope that may be unavailable or irrelevant; (2) nonlinear models for agile maneuvering of ground vehicles with sufficient fidelity to describe the coupling between surface terrain and vehicle dynamics; (3) vision-based methods and algorithms for adaptive perception with range sufficient for predictive high speed motion control, considering both obstacles and surface condition. Sensing modality should be limited to those commonly available such as 2D (visual and/or infrared) and range (LIDAR and/or radar) cameras; (4) nonlinear control algorithms that handle adaptive perception, surface condition sensing, and control objectives in an integrated framework; (5) methods for “human in the loop” control, in which a human is providing high level guidance commands, possibly in real time: The control system must evaluate whether the command is implementable. Whether the control is implementable or not, the vehicle must react appropriately; (6) approaches to logical analysis of ensuing cyber-physical system to ensure that time and resource constraints necessary to make the tight integration of perception, control, and real-time response to human commands possible.

Impact: Military, peace-keeping, and humanitarian operations increasingly take place in urban regions, with a highly dynamic, adaptive enemy exhibiting behavior which is difficult to predict. This effort will advance the capabilities of unmanned ground vehicles, particularly the Future Combat Systems, to support military operation under such challenging operational conditions and environments.

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ARMY FY2010 MURI TOPIC # 25

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Structured Modeling for Low-Density Languages

Background: Computational linguistics (CL) methods are used in software to translate text from one natural language to another. Over the past decade, there has been progress in developing machine translation (MT) capabilities for high-density languages, where there are a great number of paired documents available on which to train the software. At a basic level, MT performs substitution of words in one natural language for words in another. Corpus data and statistical techniques improve the handling of phrases, idioms, and anomalies. Customization improves output by limiting the scope of substitutions. In this manner, current MT systems are data-rich, statistics-driven, and labor-intensive; rather than relying on models or explicit rules, they train on immense amounts of human-translated and parsed texts. DoD's future need for MT is substantial as the US maintains troops in 144 countries, many with low-density languages, and our communications and signals intelligence processes are overwhelmed in both volume and numbers of languages to monitor. Our current corpus-based MT systems are unable to produce the quality of a human translator, and the immense amount of paired corpora required for these systems are extremely expensive to develop and do not exist for many languages. Proceeding along the current path of MT development for languages of potential DoD interest would be extremely resource-intensive, would take many decades, and would remain of limited quality. Recent progress in semantic and natural language processing (NLP) areas of text analysis (TA) promises better capabilities as the models are refined and used for automatic summarization (AS), abstraction, understanding, question answering, and text simplification. Ongoing issues include evaluation of quality of MT and TA and the ability to assess the value of information from text. NLP is a technically demanding subfield of artificial intelligence (AI) and CL and much of its science involves modeling, computing, probability, statistics, and machine learning techniques. What is needed now is a structured modeling approach to MT and NLP with the additional advantage that an MT engine based on language structure rather than stochastic substitutions will open the way to enhanced TA capabilities.

Objective: This project seeks to: 1) Develop the science, technology, and tools for efficient machine translation in a low-density environment, in particular, the architectures, models, and metrics for more structured and robust MT models. 2) Use the newly developed MT models for TA (i.e., paraphrase, summarize, correlate, answer questions) and produce accurate reports. 3) Demonstrate the progress of this work by establishing the MT framework to develop language resource tools for a medium- and low-density language.

Research Concentration Areas: Interdisciplinary research is needed to: 1) Improve the quality of MT by developing architectures, (linguistic, psychological, and mathematical) models and metrics for inclusion of semantics and pragmatics and building more effective MT tools. 2) Use the new MT tools, demonstrating their utility in two-way translation of low/medium-level resourced language. 3) Improve the quality of NLP by moving closer to full comprehension with the goal of natural language understanding. 4) Use the MT and NLP models to paraphrase, interpret, and extract ideas and themes from documents. This focuses attention on text content analysis -- who did what to whom and when, so that further analysis can be performed. 5) Use the models to summarize, correlate, and distill the content to answers of general or specific questions about the information in the sources. Specifically, AS must create a shortened version still containing the important points of the original text and giving answers to user queries.

Impact: Intelligence processing, which relies on translation of sources in determining the most valuable and meaningful information, would be vastly improved and information overload reduced. This research will advance both intelligence processing and network science.

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ARMY FY2010 MURI TOPIC # 26

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Directed Self-Assembly of Reconfigurable Materials

Background: The bottoms-up assembly of materials enables scientists to exercise exquisite control over the local chemistry as a means of adding new functionality and boosting overall material performance. Recent studies have demonstrated the feasibility of using tailored interactions with small molecules to drive the assembly of inorganic nanoparticles into larger structures spanning multiple length scales. Similarly, dynamic assembly processes have been studied in which the bonding and network structures can undergo disassembly and reassembly in route to their final structures. However, the design and assembly of complex structures with specifically targeted properties still remains beyond our grasp. By extension, one can imagine the insertion of building blocks capable of dynamically altering their configuration, varying their coupling interaction, and even switching between physical states. When incorporated into larger structures these elements would be able to dynamically alter the template architecture that is available for subsequent growth, and also lead to the design of 'smart' materials that possess the ability to change their properties in response to external command signals or environmental cues. This program seeks to develop the strategies and techniques needed to design and massively self assemble multi-component systems into engineered hierarchical structures that have specifically targeted properties and incorporate reconfigurable elements that provide materials with unprecedented dynamic response.

Objective: Develop the scientific foundations needed to design and self assemble reconfigurable materials with radically increased complexity and functionality.

Research Concentration Areas: An aggressive research program is being sought that is directed at the design and self assembly of nanoparticles into complex hierarchical architectures where transforming elements have been intentionally incorporated into the structure to guide the assembly process and ultimately to yield reconfigurable material systems with specifically tailored 'smart' electronic and optical properties. Research thrusts should include, but not necessarily be limited to:

1) Staged Assembly of Nanoparticles: Develop the techniques needed for staging individual attachment steps into a sequential assembly that leads to complex and/or hierarchical architectures with unique properties. Opportunities for manipulating the assembly process by utilizing aspects of shape, intermolecular interactions, induced conformation changes, functionalized adduct and site specific binding groups, molecule-to-substrate interactions, and external fields need to be fully developed. Assembly may be performed on templated surfaces augmented with electrical contacts, but it should also include a variety of other noncontact approaches for driving the assembly process.

2) Integration of Reconfigurable Elements: Develop a methodology for incorporating building blocks capable of dynamically altering their configuration, varying their coupling interactions, and switching between physical states. Use these elements to dynamically alter the template architecture and the binding interactions that are expressed during different stages of the directed-assembly process, and to yield 'smart' materials that possess the ability to change their properties in response to external command signals or environmental cues. Avenues for the capture, conversion, and/or transduction of various forms of energy should be incorporated into the design as a means of driving the assembly and/or reconfiguration processes.

3) Complementary Theory: Formulate new theoretical tools and computational methods capable of modeling the self-assembly process and identifying valid self-assembly pathways that lead to stable hierarchical architectures and desired functionality. The theory needs to also be able to incorporate

robust reconfigurability into its methodology and ultimately predict the range of dynamic behavior that can be achieved in these systems. These predictions need to be experimentally validated.

Impact: A robust research program that facilitates the design and fabrication of reconfigurable matter, capable of autonomously responding to its environment, would have profound implications in enhancing the capabilities of the future warfighter. Other potential applications include materials for adaptive optics, tunable negative index materials, laser protection, autonomous sensors, self-tuning communications and electronic systems, temperature stabilization, synthetic immunogens and clotting agents, microrobotic systems, energy harvesting, H storage, and rf-ID.

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ARMY FY2010 MURI TOPIC # 27

Submit white papers and proposals to the Army Research Office

"Atomtronics": A generalized electronics

Background: Solid state electronics, heralded by the transistor, transformed both civilian and military culture within a generation. Yet, there is only a single kind of electron: its mass, charge and spin (and thus quantum statistics as well) are unalterable. Atoms, on the other hand, come with different masses, can have multiple charge states, and a variety of spin and other internal quantum states. Accordingly, “atomtronics” envisions an atom-based rather than electron-based device physics analogous to and going beyond electronics. Breakthroughs in cold atom physics and degenerate quantum gases presage this new kind of device physics. That cold atom science has resulted in atomic analogies to other technologies such as optics and lasers suggests that the same may be repeated with electronics. Very good analogies of solids and junctions can be made with trapped atoms. It is now well-known how one, two and three dimensional structures with essentially any lattice geometry can be formed in cold, trapped atoms. Presently, a few theory papers are pointing the way to simple devices.

The most apparent, but not necessarily the only, approach to atomtronics is through optical lattices, where Bloch’s theorem holds. Band structure is the first basis on which we understand traditional (electronic) metal, insulator, and semiconductor behavior. Interaction and disorder modifies this, and exploration of Mott-like and Anderson like insulators and transitions is envisioned as well. Doping can be mimicked by modifying atoms in certain wells or by locally modifying the lattice potential which is the better analogy. The latter can be done with additional optical fields. Such defects could be deeper or shallower wells, or missing or additional sites. Recent breakthroughs involving three dimensional optical lattices and the loading of atoms into lattices with reasonably long lifetime have set the stage for atomtronics.

Objective: The goals of this MURI are to utilize both junctions and optical lattices – or some other approach – to create device-like functional units that are (i) analogous to discrete electronic components and (ii) totally novel as enabled by using atoms. A major goal is to exploit mass, statistics, and internal quantum states not present in electrons (and hence not in electronics) to design new functions and new capabilities. Uses beyond atom amplifiers for atom interferometry are desired.

Research Concentration Areas: Suggested research areas include, but are not limited to: (i) Implementation through an optical lattice or some other structure: free-space, chip-based, or other suitable platform. (ii) Implement “doping” such as through the introduction of “defects” in a lattice. (iii) Exploration of device-like functional units enabled by additional degrees of freedom. Research addressing (i) coherent operation and what it would add and (ii) device concepts beyond analogies not only of band structure but of strong interaction and disorder, are of interest.

Successful progress in this area will require coordinated efforts involving separate communities, including atomic physics theory/experiment, condensed matter/materials science theory/experiment, optics, and electrical engineering.

Impact: Research in this field will provide a fundamental understanding of atom-based device physics and will have great implications for “tailor-making” new devices with novel and desirable functionalities. It will advance the state of knowledge in atomic physics and in condensed-matter physics, including understanding of the role (and uses) of spin statistics, and the accessibility of numerous charge and internal states, to explore beyond electronics for as-yet unknown properties and uses in addition to atom amplifiers for interferometry. Future work building upon the results of this topic may result in advanced computation for information processing such as logistics optimization and sensing for battlespace awareness.

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ARMY FY2010 MURI TOPIC # 28

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Bio-Electronic Templates for Interfacing to the Nanoscale

Background: Nanoscale-based science and technology is profoundly impacting chemistry, biology and the material sciences in capability areas of high relevance to the U.S. Army and DoD. Thus far it has not been as disruptive a force in the core electronics areas (sensing, data processing and computation), primarily as a result of the overwhelming difficulties associated with interfacing electro-optical signals to molecular-level structures and devices. More specifically, while many nanoelectronic device and system concepts have emerged in recent years suggesting promise for enabling enormous increases in electronic functionality, integration and speed, these payoffs will not be realized until interfacing methodologies and technologies are perfected that allow for: probing molecular-level phenomenology; analyzing signal propagation within nanoscale building blocks; and guiding the hierarchical integration of 3D nanoarchitectures. While traditional top-down (e.g., nano-patterning) and emerging bottom-up (e.g., self-assembly) fabrication techniques are alone inadequate for successfully interfacing to the nanoscale, recent breakthroughs now make it feasible to leverage bio-inspired techniques for creating nanoscaffold templates comprised of biomolecular units paired with inorganic electronic materials as well as electrical and/or optical signal transduction points and array complexes.

Objective: Application of proven bio-based self-assembly (e.g., DNA origami) to develop: (1) micron-sized scaffolds that incorporate functional molecular units (e.g., bio-molecular tunneling transistor devices); and (2) nano-structured semiconductor platforms with novel signal transduction interfaces (e.g., nanowire plasmonics; nano-antennas, meta-material lenses), both in pre-defined organized patterns such that they may be aligned with state-of-the-art electronic metrology techniques to enable RF-THz-IR-Optical interrogation of functional bio-molecular devices. The resulting bio-electronic template-pairs should be used to achieve the first-time electronic interfacing of electronic and/or photonic signals to the nanoscale for the purpose of studying electro-optical functionality and phenomenology in molecular devices and systems. These nanotechnology-enabled scientific studies will provide new insights into bio-based signal propagation and define new nanoelectronic paradigms for future sensing, data processing and computation applications.

Research Concentration Areas: Suggested research areas include, but are not limited to biology, chemistry, nano/molecular electronics, quantum physics, and electrical engineering. In particular, bio-inspired self-assembly and guided assembly will be needed as well as chemistry-guided molecular synthesis and physics-based modeling of molecular electro-optical functionality. Other specific areas include semiconductor-based nano-device design, nano-patterning and metrology; RF-THz-IR-Optical circuits/guides implementation, testing and measurement.

Impact: An entirely new methodology for interfacing to the nanoscale in the context of electronic signal application and extraction. This technology would enable pioneering studies in biological-based molecules and systems and contribute new insights and discoveries in bio-molecular electronics with relevance to future sensing, data processing and computation. Expected high-importance impact areas include, but are not limited to: neuron signal science and phenomenology; bio-based sensing of chemical, biological, radiological and explosive agents; novel bio-molecular devices for RF-THz-IR-Optical digital/analog applications; and novel diagnostic and treatment methodologies for bio-medical applications.

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ARMY FY2010 MURI TOPIC # 29

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Ion Transport in Complex Heterogeneous Organic Materials

Background: From primitive biological organisms to the most complex modern electronic devices, transport in complex materials provides the foundation for an extraordinary breadth of compact and robust function across a tremendous range of ambient conditions. Yet a fundamental understanding of even the simplest forms of ion exchange and conduction is limited, particularly at the molecular scale, where the effects of charge, concentration, and conformation quickly become convoluted. Furthermore, even when new insights and novel methods for predicting ion transport through complex structures have been developed and substantiated, processing and assembly strategies are inadequate to synthesize novel membranes based on these insights and principles. A fundamental understanding of ion transport and basic fabrication science is critical to provide the basis for the future design of anion-exchange membranes. There are several recent breakthroughs that make this the opportune time to carry out this research, including a new synthetic procedure based on radiation grafting that enables the synthesis of new quaternary ammonium-based alkaline anion-exchange materials with targeted transport and mechanical properties, new NMR techniques to characterize diffusion rates through anionic materials, improved computational algorithms capable of dealing with complex asymmetric chemical interactions and anisotropic polymer films, and new materials assembly and fabrication methodologies including the use of nanocomposites with new tailored nanomaterials.

Objective: This MURI seeks to develop a fundamental understanding of ion exchange and conduction in complex heterogeneous organic materials, and use this knowledge to synthesize new chemically stable, high conductivity alkaline polymers, fabricate mechanically robust thin films based on them, and demonstrate revolutionary combinations of anion transport and mechanical integrity. The resultant thin films must be chemically stable under aggressive alkaline conditions with without no reduction in conductivity or loss of mechanical properties over time.

Research Concentration Areas: Suggested research areas include, but are not limited to:
(1) synthesis, processing, and characterization of new chemically stable hydroxide conducting polymer materials; (2) high-fidelity chemistry-based predictive models of the mechanisms of transport within polymeric membranes, and validation through quantitative experimental studies over a broad range of ambient conditions and external stimuli; (3) investigation of novel polymer processing techniques and new material architectures capable of generating thin films, while simultaneously having high conductivity, tensile modulus, strength, and elongation to break; (4) analytical studies capable of providing new insights into the physics governing transport in custom alkaline exchange membrane materials; and (5) development of new advanced spectroscopic techniques to characterize polymer transport and degradation.

Impact: Anion conductive polymers have the potential to enable multiple new revolutionary technologies, including selective transport membranes and alkaline-exchange membrane fuel cells. Such fuel cells could directly use hydrocarbon fuels available to the military. These technologies will provide revolutionary new capabilities for both the military and civilian sectors.

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ARMY FY2010 MURI TOPIC # 30

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Defect Reduction in Superlattice Materials

Background: Predictions of long wave infrared detector performance exceeding that of current state of the art mercury cadmium telluride (MCT) photodiodes has generated a great deal of interest recently in III-V superlattices with staggered (*i.e.* type II-III) heterojunction band alignments (T2SLs). Compared with MCT, the T2SL has a larger electron effective mass which should result in lower diode tunneling currents. The staggered band alignments within the superlattice gives rise to an effective bandgap that can be tuned over a very wide range of infrared energies by changing layer thickness and/or composition. It has been shown that with proper superlattice design, infrared absorption coefficients comparable to those of MCT are possible. Theoretically, band structure engineering can be used to eliminate many of the Auger recombination channels that currently limit the high temperature performance of MCT, with predicted minority carrier lifetimes orders of magnitude larger. However, the predicted performance improvements have not been realized due to the presence of a high density of defect and interface related carrier traps that limit the lifetimes in the T2SL material to the range of 1 to 100 nsec. A research program that focuses on the fundamental physics of these carrier traps is needed to enable the development of material growth and device processing techniques that maximize the performance of the T2SL system.

Objective: Determine and understand the relationship between minority-carrier lifetimes and classes of defects in superlattice materials. Formulate strategies for growth and post processing to eliminate or mitigate defects.

Research Concentration Areas: Research areas shall include, but are not limited to Materials Science, Physics, Chemistry, and Electrical Engineering.

Physical Chemistry of defects in T2SLs: Determine which types of defects are energetically favorable under the growth environment, and how that environment can be altered to make the defect formation less favorable. Identify the dominant defects and model their effects on the carrier trapping and transport. Apart from eliminating the defects, determine steps to minimize their influence on the minority carriers, such as solid state chemistry routes to remove mid-gap states.

Growth of new structures: Formulate growth techniques and identify growth conditions that reduce the concentrations of those defects that dominate the background carrier concentrations and lifetimes. Explore defect sensitive *in-situ* probes to monitor T2SL growth. Develop improved methods for passivating exposed superlattice surfaces.

Characterization: Devise techniques to probe defects in T2SL structures. Combine structural investigations with electron dynamics to verify the theory and modeling. For example, a local pump-probe technique may be able to study the dynamics in isolated defects. Bulk, interface, and surface defects are all relevant. Develop improved experiments for measuring carrier lifetimes in type-II superlattices. Measure vertical mobilities in these superlattices.

Impact: Understanding defects at the basic level in these superlattice materials will promote advancements in lasers and modulators as well as infrared detectors. For detectors, lifetime improvements will allow the next generation of focal plane arrays with increased long wave resolution, much larger array formats, broader spectral range into the very long wave infrared, and higher operating temperature to reduce life cycle costs. In addition, use of the III-V materials family will leverage the vast infrastructure already in place to further reduce the cost.

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