ONR BAA Announcement # 04-021

BROAD AGENCY ANNOUNCEMENT (BAA)

INTRODUCTION:

This publication constitutes a Broad Agency Announcement (BAA) as contemplated in Federal Acquisition Regulation (FAR) 6.102(d)(2) and Department of Defense Grant and Agreement Regulation (DODGARS) 22.315. A formal Request for Proposals (RFP), solicitation, and/or additional information regarding this announcement will not be issued.

The Office of Naval Research (ONR) will not issue paper copies of this announcement. The ONR and Department of Defense (DoD) agencies involved in this program reserve the right to select for award all, some or none of the proposals submitted in response to this announcement. 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").

I. <u>GENERAL INFORMATION</u>

1. Agency Name

Office of Naval Research
800 North Quincy Street
Ballston Centre Tower One
Arlington, VA 22217-5660

2. Research Opportunity Title

Multidisciplinary University Research Initiative (MURI)

3. Program Name

Fiscal Year 2005 Department of Defense Multidisciplinary Research Program of the University Research Initiative

4. Research Opportunity Number

BAA 04-021

5. Response Date

White Papers: Thursday, 12 August 2004

Full Proposals: Thursday, 18 November 2004

6. Research Opportunity Description

The Multidisciplinary University Research Initiative (MURI) program supports basic science and/or engineering research at institutions of higher education (hereafter referred to as "universities") that is of critical importance to national defense. The program is focused on multidisciplinary research efforts that intersect more than one traditional science and engineering discipline.

The Fiscal Year (FY) 2005 MURI competition is specifically for the twenty-six (26) topics listed below. Detailed descriptions of the topics can be found in Section VIII., 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 (8) should be mailed to the Army Research Office (ARO):

(1) Cross-Disciplinary Approach to the Modeling, Analysis, and Control of Wireless Communications Networks
(2) Control of Networked Autonomous and Semi-Autonomous Vehicle Swarms Inspired by Nature
(3) Standoff Inverse Analysis and Manipulation of Electronic Systems (SIAMES)
(4) Training for the Networked Battlefield
(5) Quantum Imaging
(6) Advanced Magnetic Resonance Force Microscopy to Single Nuclear Spin Detection
(7) Material Engineering of Lattice-Mismatched Semiconductor Systems
(8) Enabling Science for Future Force Insensitive Munitions

White papers and full proposals addressing the following topics (9) through (18) should be mailed to the Office of Naval Research (ONR):

(9) Detection and Sensing Below the Shot Noise Limit
(10) Novel Dielectric Materials for High Pulsed Power Capacitors
(11) Multi-Energy Processing Science
(12) Realtime Sensing, Prediction, and Response to Evolving Nonlinear Wavefields
(13) Materials Manufacturing Processes, Interface Control, and Reliability of Nanostructure-Enhanced Devices for Energy Conversion and Realization of High Performance Systems
(14) GaN Based mm-Wave Sources
(15) Exploitation of the Coherent Structures in River and Estuarine Flows for DoD Operations in Denied Areas
(16) Magnetic Detection Science and Technology
(17) Revolutionary Approaches to Hypersonic Materials
(18) Radically New Approaches for Robust Speech-to-Text

White papers and full proposals addressing the following topics (19) through (26) should be mailed to the sent to Air Force Office of Scientific Research (AFOSR):

(19) Radiation Effects on Emerging Electronic Materials and Devices
(20) Extreme Light Material-Based Diagnostics
(21) Computational Modeling of Adversary Attitudes and Behaviors
(22) Water-Based Photobiological Production of Hydrogen Fuel
(23) Waveform Diversity for Full Spectral Dominance
(24) Closed-Loop Aerodynamic Flow Control
(25) Multistage Electromagnetic (EM) and Laser Launchers for Affordable, Rapid Access to Space
(26) Biomimetic Multifunctional Composites for “Autonomic” Aerospace Structures

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 as the responsible technical point of contact. Similarly, one institution will be the primary awardee for the purpose of award execution. 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.

Historically Black Colleges and Universities and Minority Institutions (HBCU/MIs) (as defined by 10 U.S.C. 2323a (1) (c)) are encouraged to participate in the MURI program, either as the lead institution or as a member of a team. However, no specific funds are allocated for HBCU/MI participation.

7. Point(s) of Contact

A Research Topic Chief is identified for each specific MURI Topic. Questions of a technical nature shall be directed to the Research Topic Chief identified in Section VIII of this BAA.

Questions of a policy nature shall be directed to the following Point of Contact:

Office of Naval Research MURI Program Point of Contact:

Dr. Donald E. Polk
Director, Corporate Programs Division, ONR Code 363
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5660
Telephone Number: (703) 696-4111
Facsimile Number: (703) 588-1013
Email Address: 363_MURI@onr.navy.mil

Questions of a business nature shall be directed to the following Business Point of Contact, as specified below:

ONR Business Point of Contact:

Vera M. Carroll
Acquisition Branch Head
Contract and Grant Awards, Management
ONR Code 251
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5660
Telephone Number: (703) 696-2610
Facsimile Number: (703) 696-0066
Email Address: carrolv@onr.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 Basic and Applied Scientific Research

10. Catalog of Federal Domestic Assistance (CFDA) Titles

CFDA Title: Basic and Applied Scientific Research

11. Additional Information

The Non-ONR Agency Information:

Air Force Office of Scientific Research
4015 Wilson Boulevard, Room 713
Arlington, VA 22203-1954

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

The previous MURI competition comprised ONR BAA #03-012 dated 23 June 2003 for the FY04 Multidisciplinary University Research Initiative Program.

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 base period of three years, to be funded incrementally or as options. Two additional years of funding as an option are possible, to bring the total maximum term of the award to five years.

Total amount of funding for five years available for grants resulting from this FY05 MURI BAA is estimated to be about $135M, pending out-year appropriations. It is anticipated that the average award will be $1M per year, with the funding for each award dependent on the scope of the proposed research. **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), with degree-granting programs in science and/or engineering. Ineligible organizations (e.g. industry, government, and non-profit research laboratories) or foreign universities may collaborate on the research but may not receive MURI funds. When a modest amount of additional funding for a DoD laboratory or a Federally Funded Research and Development Center (FFRDC) 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 program manager. If approved, the supplemental proposal will be funded by the responsible agency using non-URI funds.

The Canadian government, through Defense Research and Development Canada, has expressed an interest in encouraging collaboration between Canadian researchers and U.S. researchers on the MURI program in research areas of mutual interest. Canadian university researchers, since they are not eligible to receive MURI funds, will be using their own resources that, most likely, will be provided by Canadian government granting agencies. Potential proposers are encouraged to take advantage of this opportunity to collaborate and team with Canadian researchers at no additional cost to DoD if there is suitable expertise that can enhance and strengthen the MURI project.

IV. APPLICATION AND SUBMISSION INFORMATION

1. Application and Submission Process

The proposal submission process is in two stages. Prospective proposers are encouraged to submit white papers. The reason for requesting white papers is 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 to the proposer to encourage or discourage them to submit full proposals. White papers arriving after the deadline may not receive, and therefore may not benefit from, the informal feedback. However, all proposals submitted under the terms and conditions cited in the BAA will be reviewed regardless of the feedback on, or lack of, a white paper.

The due date for white papers is no later than 4:00 PM (local time) on 12 August 2004. Notification of white papers submissions will be announced on or about 09 September 2004. The due date for full proposals is no later than 4:00 PM (local time) on 18 November 2004. Notification of selection of award will be announced on or about 17 February 2005.

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. White papers and full proposals 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. Grants awarded under this announcement will be unclassified.

White Paper Format

A WHITE PAPER MAY BE SUBMITTED EITHER ELECTRONICALLY OR IN HARD COPY FORM. FOR ELECTRONIC AND HARD COPY SUBMISSION:

- Paper Size – 8.5 x 11 inch paper
- Margins – 1 inch
- Spacing – single or double-spaced
- Font – Times New Roman, 12 point
- Number of Pages – no more than four (4) single-sided pages (excluding cover and curriculum vitae). White papers exceeding the page limit may not be evaluated.
- Copies – one (1) original and two (2) copies

Full Proposal Format : Volume 1 - Technical Proposal and Volume 2 - Cost Proposal

A FULL PROPOSAL MUST BE SUBMITTED IN HARD COPY FORM.

- Paper Size – 8.5 x 11 inch paper
- Margins – 1 inch
- Spacing – single or double-spaced
- Font – Times New Roman, 12 point
- Number of Pages – Volume 1 is limited to no more than twenty (20) single-sided pages. Volume 2 has no page limitation. The cover, table of contents, and curriculum vitae are excluded from the page limitations. Full proposals exceeding the page limit may not be evaluated.
- Copies – one (1) original and five (5) copies.

White Paper Content

- Cover Page – The cover page shall be labeled "PROPOSAL WHITE PAPER" and shall include the BAA number, proposed title, and proposer's technical point of contact, with telephone number, facsimile number, and Internet address.
- 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

White papers should be sent to the responsible Research Topic Chief at the agency specified for the topic. 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.

A short cover letter (one page) may be included and is excluded from the page limitation.
It is not necessary for white papers to carry official institutional signatures.

Full Proposal Content

The full proposal should be broken down into two volumes, Volume 1 – Technical Proposal and Volume 2 – Cost Proposal. Volume 1 should consist of a Cover, Table of Contents, Executive Summary, Statement of Work, Technical Approach, Project Schedule and Milestones, Assertion of Data Rights, Deliverables, Management Approach, and Personnel. Volume 2 should consist of a detailed cost breakdown by cost category for the budget periods provided below and a cost breakdown by task/subtask.

VOLUME 1: Technical Proposal

- **<u>Cover:</u>** A completed cover (consisting of the two single-sided pages provided in Section IX) MUST be used as the first two pages of the proposal. There should be no other page before this cover.

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

- **<u>Executive Summary:</u>** Provide a summary of the research problem, technical approaches, anticipated outcome of the research if successful, and impact on DoD capabilities.

- **<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, proposals must include a severable self-standing SOW, without any proprietary restrictions, which can be attached to a grant award.

- **<u>Technical Approach:</u>**

  (a) 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 progress elsewhere. Include appropriate literature citations and references. Discuss the nature of expected results. Discuss potential applications to defense missions and requirements.

  (b) 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.

- **<u>Project Schedule and Milestones:</u>** A summary of the schedule of events and milestones.

- **<u>Assertion of Data Rights:</u>** A summary of any proprietary rights to pre-existing results, prototypes, or systems supporting and/or necessary for the use of the research, results, and/or prototype. Any data rights asserted in other parts of the proposal that would impact the rights in this section must be cross-referenced. If there are proprietary rights, the proposer must explain how these affect its ability to deliver research data, subsystems and toolkits for integration. Additionally, proposers must explain how the program goals are achievable in light of these proprietary limitations. If there are no claims of proprietary rights in pre-existing data, this section shall consist of a statement to that effect.

- **<u>Deliverables:</u>** 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 is 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. Particularly 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 technical program manager. 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 mange 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.

- **Curriculum Vitae:** Include curriculum vitae of the Principal Investigator and key co-investigators.

VOLUME 2: Cost Proposal

The Cost Proposal shall consist of a cover and two parts: Part 1 will provide a detailed cost breakdown of all costs by cost category by the funding periods described below and Part 2 will provide a cost breakdown by task/sub-task corresponding to the task numbers in the proposed

Statement of Work. Options must be separately priced. There is no page limitation on the cost proposal.

Cover: The use of the SF 1411 is optional. The words "Cost Proposal" and the following information should appear on the cover:

- BAA number
- Title of Proposal
- Identity of the prime proposer and a complete list of proposed subawards, if applicable
- Principal Investigator (name, mailing address, phone and fax numbers, email address)
- Administrative/business contact (name, address, phone and fax numbers, email address) and
- Duration of effort (separately identify basic effort and proposed option)

Part 1: Detailed breakdown of all costs by cost category by the calendar periods stated below. For budget purposes, use an award start date of 01 May 2005. For the three-year base grant, the cost should be broken down to reflect funding increment periods of:

(1) Five months (01 May 05 to 30 Sep 05),
(2) Twelve months (01 Oct 05 to 30 Sep 06),
(3) Twelve months (01 Oct 06 to 30 Sep 07), and
(4) Seven months (01 Oct 07 to 30 Apr 08).

Note that the budget for each of the calendar periods (e.g. 01 May 05 to 30 Sep 05) 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) Five months (01 May 08 to 30 Sep 08),
(2) Twelve months (01 Oct 08 to 30 Sep 09), and
(3) Seven months (01 Oct 09 to 30 Apr 10).

The annual budget should be relatively flat, i.e. about the same amount per year. (The five-month budget and the seven-month budget should add up to an amount about equal to the twelve- month budget.) However, if there is anticipated difficulty in effectively spending the funds at the steady-state rate for the entire first budget period, the initial five-month budget can be reduced to account for start-up effects. Similarly, the initial five-month budget can be somewhat higher if substantial equipment funding is requested. Elements of the budget should include:

- Direct Labor – Individual labor category or person, with associated labor hours and unburdened direct labor rates
- Indirect Costs – Fringe Benefits, Overhead, G&A, COM, etc. (Must show base amount and rate)

- Travel – Number of trips, destination, duration, etc.
- Subcontract – A cost proposal as detailed as the proposer's cost proposal will be required to be submitted by the subcontractor. The subcontractor's cost proposal can be provided in a sealed envelope with the proposer's cost proposal.
- Consultant – Provide consultant agreement or other document that verifies the proposed loaded daily/hourly rate. Include a description of the nature of and the need for any consultant's participation. Strong justification must be provided, and consultants are to be used only under exceptional circumstances where no equivalent expertise can be found at a participating university.
- Materials should be specifically itemized with costs or estimated costs. An explanation of any estimating factors, including their derivation and application, shall be provided. Include a brief description of the proposer's procurement method to be used (competition, engineering estimate, market survey, etc.).
- Other Directs Costs, particularly any proposed items of equipment or facilities. Equipment and facilities generally must be furnished by the contractor/recipient. (Justifications must be provided when Government funding for such items is sought.) Include a brief description of the proposer's procurement method to be used (competition, engineering estimate, market survey, etc.).

Part 2 : Cost breakdown by task/sub-task using the same task numbers as in the Statement of Work.

3. Significant Dates and Times

Schedule of Events		
Event	**Date**	**Time (Local Time)**
White Papers Due Date	12 August 2004	4:00 PM.
Notification of Initial DoD Evaluations of White Papers	09 September 2004*	
Full Proposals Due Date	18 November 2004	4:00 PM
Notification of Selection for Award	17 February 2005*	
Start Date of Grant	01 May 2005*	

***These dates are estimates as of the date of this announcement.**

4. Submission of Late Proposals

Any proposal, modification, or revision, that is received at the designated Government office after the exact time specified for receipt of proposals is "late" and will not be considered unless it is received before award is made, the contracting officer determines that accepting the late proposal would not unduly delay the acquisition, and:

(a) the proposal was sent, to the address specified for the designated agency, by U.S. Postal Service Express Mail three or more business days prior to the date specified for the receipt of proposals (the term "business days" excludes weekends and U.S. federal holidays) ; or

(b) there is acceptable evidence to establish that it was received at the Government installation designated for receipt of proposals and was under the Government's control prior to the time set for receipt of proposals; or

(c) it was the only proposal received.

However, a late modification of an otherwise timely and successful proposal that makes its terms more favorable to the Government will be considered at any time it is received and may be accepted.

Acceptable evidence to establish the time of receipt at the Government installation includes the time/date stamp of that installation on the proposal wrapper, other documentary evidence of receipt maintained by the installation, or oral testimony or statements of Government personnel.

If an emergency or unanticipated event interrupts normal Government processes so that proposals cannot be received at the Government office designated for receipt of proposals by the exact time specified in the announcement, and urgent Government requirements preclude amendment of the announcement closing date, the time specified for receipt of proposals will be deemed to be extend to the same time of day specified in the announcement on the first work day on which normal Government processes resume.

The DoD agencies will promptly notify any proposer if its proposal, modifications, or revision was received late and will inform the proposer whether its proposal will be considered.

Note that proposals delivered by commercial carriers are considered "hand carried" and that no exception can be made to allow such proposals to be considered if for any reason they are received after the deadline. Proposers are advised that some proposals responding to past announcements that were sent via commercial carriers were delayed during shipment and arrived after the deadlines, typically by one or two days. To decrease the probability that proposals delivered by commercial carriers will arrive after the deadline and thus be ineligible to compete, proposers are urged to schedule delivery to occur several days before the deadline.

5. Address for the Submission of White Papers and Full Proposals

White papers should be sent directly to the attention of the responsible Research Topic Chief at the agency specified for the topic as stated in Section VIII. using the addresses given below.

White papers and full proposals addressing topics (1) to (8) should be sent to the Army Research Office at the following address.

For delivery by ordinary First Class or Priority Mail (but not Express Mail) through the U.S. Postal Service:

U.S. Army Research Office (FY05 MURI)
P. O. Box 12211

Research Triangle Park, NC 27709-2211

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

U.S. Army Research Office (FY05 MURI)
For full proposals include: ATTN: Dr. Larry Russell
For white papers include: ATTN: list name of responsible Research Topic Chief
4300 S. Miami Blvd
Durham, NC 27703-9142
919-549-4211

White papers and full proposals addressing topics (9) to (18) should be sent to the Office of Naval Research at the following address.

Office of Naval Research
For full proposals include: ATTN: Mailroom (MURI/ONR Code 363)
For white papers include: ATTN: list name of responsible Research Topic Chief
800 North Quincy Street
Tower 1, Room 304
Arlington, VA 22217-5660
Point of Contact: Paula Barden
703-696-4111

White papers and full proposals addressing topics (19) to (26) should be sent to the Air Force Office of Scientific Research at the following address.

Air Force Office of Scientific Research
For full proposals include: ATTN: Mailroom (MURI 05)
For white papers include: ATTN: list name of responsible Research Topic Chief
4015 Wilson Boulevard, Room 713
Arlington, VA 22203-1954
Point of Contact: Dr. Spencer Wu
703-696-7315

NOTE: FULL PROPOSALS SENT BY FAX OR E-MAIL WILL NOT BE CONSIDERED.

Acknowledgment of receipt of a proposal by an agency will be by way of the page in Section X, Acknowledgment Form. To obtain acknowledgment of receipt of a proposal, proposer should self-address and place a first class stamp on the form and CLIP TO ORIGINAL COPY OF THE PROPOSAL (DO NOT TAPE OR STAPLE); the form will be mailed back to the proposer shortly after the deadline for receipt of proposals.

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 will be evaluated using the following criteria. The first three 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 Department of Defense missions; and

(3) impact of plans to enhance 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).

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

(4) the qualifications and availability of the principal investigator and key co-investigators.

(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.)

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 employed in the government.

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 employed in the government. Evaluation panel members are required to sign "no conflict of interest" and non-disclosure agreements (NDA to protect proprietary and source-selection information.

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

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

- Certifications – Proposals should be accompanied by a completed certification package which can be accessed on the ONR Home Page at Contracts & Grants. The certification package for Grants is entitled, "Certifications for Grants and Agreements."

2. Reporting

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

VII. OTHER INFORMATION

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

Each proposer must provide a very specific description of any equipment/hardware that it needs to acquire to perform the work. This description should identify the component, nomenclature, and configuration of the equipment/hardware that it proposes to purchase for this effort. The purchase on a direct reimbursement basis of special test equipment or other equipment that is not included in a deliverable item will be evaluated for allowability on a case-by-case basis. Maximum use of Government integration, test, and experiment facilities is encouraged in each of the proposer's proposals.

Government research facilities and operational military units are available and should be considered as potential government furnished equipment/facilities. These facilities and resources are of high value and some are in constant demand by multiple programs. It is unlikely that all facilities would be used for the Multidisciplinary University Research Initiative program. The use of these facilities and resources will be negotiated as the program unfolds. Proposers should explain which of these facilities they recommend.

2. Use of Animals and Human Subjects in Research

If animals are to be utilized in the research effort proposed, the proposer must complete a DoD Animal Use Protocol with supporting documentation (copies of AAALAC accreditation and /or NIH assurance, IACUC approval, research literature database searches, and the two most recent USDA inspection reports) prior to award. Similarly, for any proposal that involves the experimental use of human subjects, the proposer must obtain approval from the proposer's committee for protection of human subjects (normally referred to as an Institutional Review Board, (IRB)). The proposer must also provide NIH (OHRP/DHHS) documentation of a Federal Wide Assurance that covers the proposed human subjects study. If the proposer does not have a Federal Wide Assurance, a DoD Single Project Assurance for that work must be completed prior to award. Please see http://www.onr.navy.mil/02/howto.htm for further information.

3. Department of Defense High Performance Computing Program

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

VIII. SPECIFIC MURI TOPICS

FY05 MURI Topic #1
Submit white papers and proposals to the Army Research Office

CROSS-DISCIPLINARY APPROACH TO THE MODELING, ANALYSIS, AND CONTROL OF WIRELESS COMMUNICATION NETWORKS

Background: At the tactical level, wireless mobile ad-hoc networks (MANETs) and large-scale, low-power sensor networks provide the current design paradigm to achieve information and sensing dominance for network centric warfare. MANETs must self-organize, be robust to frequent and unpredictable changes in topology due to mobility and node loss, and be able to handle large variations in load. Information transfer will be multi-hop, and without centralized control. Networks may become overloaded, supporting a variety of traffic types, each with their own quality of service requirements. Interference and bit errors at the physical level, congestion and delay for real time data at the network level, unreliable and intermittent connectivity, and complexity constraints are some of the challenges in designing tactical MANET protocols. Information assurance, including LPI/LPD/AJ and encryption, should be an integral part of the system.

Significant advances continue to be made in many of the sub-disciplines of MANETs, including the physical layer, routing, etc., but there remain significant challenges and unknowns in the theory of complex wireless networks. Issues include capacity, performance analysis, prediction, and scalability of protocols. It is expected that disciplines that deal with the mathematical analysis of large complex dynamic systems may offer insights, models, and approaches towards the development of a general theory of complex networks.

Objectives: Using insights from multiple disciplines in networking and complex systems, develop analytical models and tools for describing, analyzing, predicting, and controlling the behavior of mobile ad hoc networks. From this theory, analysis and design rules should be developed in order to have an impact on tactical mobile ad-hoc networks, such as those currently under development for the Army Future Combat System (FCS). This should include performance prediction, analysis of protocols, analysis of scalability, and fundamental limits.

Research Concentration Areas: The following topics should be investigated: 1. Develop the mathematical framework for modeling, analysis, design, and optimal control for MANETs. What are the fundamental limits of a multi-hop ad hoc network and the appropriate metrics? What dynamic re-configuration strategy among the network links and nodes that maximizes the throughput and minimizes delay? The framework should facilitate analytical understanding of the fundamental role of mobility in networking, and incorporate traffic characteristics such as the burstiness of data, randomly fading channels, and latency constraints. 2. Make explicit the relationships between fragility and robustness in mobile ad-hoc networks. Issues include the network layering and cross layer interaction and design. Develop a framework to model the interactions within the layered architecture, leading to a study of the fragility and robustness of the interactions between the different layers. 3. Develop a theory of protocols that scale with the number of nodes in the network, for transport, admission control, network, routing, media access control, and physical layer functions. 4. Bring the multidisciplinary approach to bear on the low energy sensor network problem. For these networks the protocol stack will be compressed in order to minimize energy consumption, and the interplay between sensing, computing or signal processing, and communications must be taken into account. 5. Large, high fidelity simulations in tactical ad-hoc networking, where hundreds and often thousands of nodes will be interacting at the network level and interfering with each other at the physical level. Based on the developed modeling and analysis framework, research the appropriate levels of abstraction to further advanced simulation techniques, encompassing mobility and scalability. 6. Mathematical developments, in areas such as nonlinear filtering and differential game-theoretic formulation, can be used for the modeling, analysis, and control of complexity of information flow pattern within a MANET environment, analysis of group coordination and formation, and centralized and decentralized control with complete or incomplete information so that the system objectives are achieved optimally.

Impact: The research and analysis that results from this topic will lead to a better understanding of how the tactical ad hoc and sensor networks will react in a battlefield deployment. This would significantly enhance DoD's ability to analyze and design robust mobile wireless networks, then predict performance in a variety of challenging environments. Therefore the tactical communications infrastructure will be more resilient and have increased throughput due to this research.

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FY05 MURI Topic #2
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CONTROL OF NETWORKED AUTONOMOUS AND SEMI-AUTONOMOUS VEHICLE SWARMS INSPIRED BY NATURE

Background: Recently, there has been an increased DoD interest in the control of group behavior for vehicular swarms, i.e., complex systems of multiple autonomous and semi-autonomous ground and air vehicles. A central driving force behind this interest is the Army's ability to conduct network-centric warfare as envisioned in the FCS (Future Combat System) program. Currently, there exists a large gap in the fundamental understanding of swarm behavior; theoretical work on artificial swarms has only started to address some of the fundamental issues regarding the forward and inverse problems of swarming, i.e., understanding emergent behavior from local interaction rules, and designing swarms with desired group behavior. It is the familiar examples of group and social behavior in nature, such as packs of wolves, flocks of birds, schools of fish, and swarms of insects, that serve as inspiration in this research theme. There exists a great potential benefit to learn from these naturally occurring examples so that engineered group behavior can be achieved that has some of the desirable properties exhibited in nature, such as: (1) emergent behavior (global goal-oriented behavior resulting from simple local individual behavior rules), (2) adaptability (ability to set and follow new goals in a changing environment), and (3) robustness (lack of dependence on a fixed leader, continuation of goal-seeking behavior in the face of disturbances). The research on swarms has largely been carried out independently by a number of different disciplines such as biology, mathematics, robotics, and computer science. The time for seeding an all-out multidisciplinary effort to gain fundamental understanding of the nonlinear dynamical and control aspects of swarm behavior has arrived. The focus of this effort ensures that the results of this program will benefit significantly from the highly effective swarming protocols found in nature.

Objective: The control of networked autonomous and semi-autonomous vehicle swarms inspired by nature program will develop the scientific underpinnings, fundamental theory, and practice for synthesis, design, and control of engineered vehicle swarms while at the same time optimizing their interaction and integration with the warfighter. The research begins with the modeling and analysis of swarms occurring in nature, and has the ultimate goal of designing and synthesizing adaptive, robust, and scalable engineered battle swarms with military applications such as strategic and tactical unmanned ground, air, and sea vehicles.

Research Concentration Areas: This is a highly multidisciplinary research effort requiring a convergence of biology, systems and control, communications, mathematics, robotics, physics, and computer science. Research is sought on modeling, analysis, simulation and synthesis to address the following aspects of the *forward* and *inverse* problems of swarming: (1) models and control algorithms including understanding emergent behavior from local rules of interaction, (2) adaptability (ability to set and follow new goals in a changing environment), (3) scalability (leveraging an understanding of the intrinsic dynamics of low-order swarms to systematically engineer large-scale swarms), (4) optimality (harnessing the highly effective biological swarm protocols), (5) robustness (lack of dependence on a fixed leader, acceptable performance in the face of disturbances), and (6) synthesis and design (the ultimate *inverse* problem).

Impact: This research has impact potential to rapidly deployable adaptive swarms of manned and unmanned vehicles, battle swarms, robotic weapon platforms, mobile communication networks, and satellite clusters, combat theater of UAV's and UGV's, battlefield awareness, operation in hazardous (chem/bio) and hostile dynamic environments, homeland defense, distributed sensing, information dominance, decision making, navigation and control, autonomous systems, dominant maneuvering, air traffic control, and embedded networks of sensors and actuators.

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FY05 MURI Topic #3
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STANDOFF INVERSE ANALYSIS AND MANIPULATION OF ELECTRONIC SYSTEMS (SIAMES)

Background: Traditional inverse scattering techniques analyze fairly general structures in terms of the linear scattering of a limited range of RF frequencies. Recent advances in global modeling have resulted in the capability for self-consistent analysis of electromagnetic phenomena and non-linear functions associated with very large and complex circuits and systems. These modeling techniques could be extended to further include self-consistent analysis of acoustic (or vibrational) effects on electronic circuitry, and analysis of nonlinear effects in complex metallic structures and electronic junctions. This opens the door to the ability to predict and analyze the unique signatures from electronic circuits and systems produced in response to external stimulus by RF and/or acoustic probe fields. The ability to detect, identify, and neutralize from a standoff location would enhance force survivability and mobility, as well provide potential homeland security applications. A wide variety of probe signals are possible: different RF frequencies which mix with the non-linear circuit elements, modulation of higher probe frequencies to couple more effectively to small circuit elements, and acoustic (or vibrational) energy to allow probing of circuitry hidden in high-density 3-D structures. The resulting analysis could in principle determine the circuit structure of an unknown device, analyze the functionality of a known device (quality control during fabrication, for example), or determine if a particular electronic system had been tampered with. The formulation of a theory for the general treatment of such problems would also provide a powerful technique to predict waveforms and probe combinations for the remote manipulation or interruption of the circuitry.

Objective: Institute a theoretical and experimental treatment of the problem of obtaining system, functional, and device information from external stimulus and monitoring of electronic systems. Determine general limitations on the information that can be extracted remotely from general categories of circuits and systems. Formulate a theory for predicting the most effective probe field combinations and signal analysis methodologies for general categories of circuits and systems, and validate the theory by experiments on a limited but useful assortment of electronic systems.

Research Concentration Areas: Areas of interest include, but are not limited to, the following: (1) modeling and understanding of the physical phenomena governing electromagnetics, non-linear RF circuits, and acoustic (or vibrational) propagation, and how these phenomena interact in electronic and electromechanical systems, (2) design, development, and testing of RF, acoustic, and vibrational probes, (3) validation experiment design and execution, (4) mathematical analysis and digital signal processing of system responses to identify patterns, (5) use of control theory to predict expected response signatures, and (6) optimization of signal detection in clutter and multiple target environments, as well as the early universe!

Impact: The capability to identify electronic systems, their functionality and their component circuits, from external sensor information, including remote sensors, and to manipulate or neutralize it, is important for the FCS at an operational level as well as at a system design level.

The ability to probe enemy or unidentified electronic systems, even ones designed to suppress normal electronic emissions, would provide major intelligence information to the commander. The capacity to remotely manipulate or interfere with these electronic functions would provide a significant countermeasure advantage. The ability to detect the signature of complex metallic structures will offer the capability to detect man-made objects other than electronic circuitry. All of these capabilities will enhance force survivability and mobility and provide potential applications in homeland security. Finally, the congestion of the RF spectrum and systems on platforms has resulted in programs designed to develop multifunctional, highly adaptive RF systems. Affordable systems will depend on high levels of circuit integration involving high-density 3-D structures. The ability to externally probe and analyze the internal operation of these complex circuits during fabrication will be critical to their low cost design and manufacturing.

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FY05 MURI Topic #4
Submit white papers and proposals to the Army Research Office

MODELING THE EFFECTS OF TRAINING FOR THE NETWORKED BATTLEFIELD

Background*:* Information networks are at the core of Defense Transformation, with warfighters as "effectors" at the nodes of the networks. Network designers must be able to predict overall decision making performance of a social organization, where member interactions are enabled or constrained by the links in the network. That is, the designer must be able to predict the performance of a social group whose individual interactions are evolving in part with the changes in outside stimuli -- a non-linear, time-variant, stochastic set of processes. While progress is being made in bringing some quantitative analytical rigor to the study of such team dynamics, sometimes called "macro-ergonomics," performance predictions assume journeyman level expertise.

Humans must be trained to utilize the benefits of networks as well as to prepare for imperfect and variably unreliable automation and the non-linearities inherent in network-driven military operations (Parasuraman, Sheridan, and Wickens, 2000). Of all domains of warfighter behavior, "training" is the domain where every leader presumes expertise or even mastery, but about which the least can be predicted. For a warfighter of a given aptitude level, the probability of successful task performance depends on the quality and extent of initial task training and of sustainment training. Unfortunately, fundamental research within the education and training communities does not exist that would allow estimating the probability of a human with given mental ability and training history performing complex tasks to standard in a dynamic and hostile environment. Existing work primarily has addressed skill retention for individual tasks (e.g., Rose, Radtke, Harris, Shettel, and Hagman (1985). Follow-on work in this regard has included the development of Isoperformance Curves (Kennedy, Jones, and Beltzley, 1986). Recent research and practical experience suggest that the performances most critical to future mission success are complex, procedural tasks associated with decision-making, battle command, and leadership, often in a mixed human-automation context such as networks.

It is modeling the effects of training for this emerging context, which requires our sustained attention and effort. Given that group and unit activities are the basis of warfare competence, it is necessary to expand the concepts underlying individual skill development to include the development of collective competence by work groups and units. This is the level at which the non-linearities and unpredictability inherent in networking technologies must be understood in order for training to support coherent battlefield control.

Objectives*:* Develop and evaluate models that predict performance improvement or decrement for a range of militarily significant individual and collective tasks that can be linked to various types and amounts of training while considering the effects of aptitude and experience.

Research Concentration Areas: It is anticipated that the key contributing disciplines are cognitive science, neuro- and macro-ergonomics, motor behavior, mathematics, and scientific computing. Areas of interest include: (1) Development of mutually coherent taxonomies of training methods, individual and collective task performance parameters, and relevant human-automation interface strategies. (2) Development of tractable algorithms for relating training to performance and system characteristics, with eventual combination into a working predictive model generalizable across a range of militarily-significant performance situations. (3) Other factors of interest are levels and types of automation, characteristics of the anticipated target population, and classical training effectiveness measures such as transfer of training, skills retention, and cost of training alternatives. Models will be judged successful if they predict up to 50% of the variance in performance for three to five simple to complex tasks for a military age population at intervals up to one year.

Impact*:* The results of this effort will enable the Army, Navy, and Air Force to decide how best to train for new tasks, provide a basis for predicting the impact of training status variables on individual and collective performance and unit readiness, and make more accurate and cost-effective system design and personnel decisions.

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FY05 MURI Topic #5
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QUANTUM IMAGING

Background: The last ten years have seen an almost unprecedented explosion of understanding in a paradoxical part of quantum mechanics. This "spooky action at a distance" formed the basis of Einstein's serious objections to the then developing theory. Though thought experiments appeared to "disprove" the physics, the subsequent understanding provided by Bell, and the test of his inequalities, showed that quantum mechanics is "right" if bizarre. It is this bizarreness that we are now coming to terms with by actually exploiting it. Quantum information, quantum computing, and quantum teleportation, all developments of this past decade, rely on the very "entanglement" that Einstein both identified and that so bothered him. Quantum imaging is yet another entry into this set of new applications of quantum mechanics. Like the others, it relies on entanglement. It offers both higher sensitivity and greater resolution imaging, and *entirely novel* kinds of imaging. Some preliminary theoretical developments took place over the past few years, and now a growing swell of interest in experimental demonstrations is in the offering, with some basic experiments already supporting these theories. Emerging optimism about the realistic prospects of quantum imaging derives from breakthroughs in quantum state preparation, in particular the production of entangled and squeezed states of many-particle systems. These developments have been spurred by research in quantum computing and quantum information, though *this is a unique and distinct niche*. The time is thus ripe. A successful program to demonstrate quantum imaging will clearly require participation of quantum physicists, but also people from fields including traditional optics and imaging, as well as electrical engineering, and materials science, and potentially others. A MURI is most apropos.

Objective: Using understanding gained in very recent years from quantum optics and quantum information science, and exploiting quantum entanglement and quantum teleportation, one can greatly improve the sensitivity and resolution of imaging, and perform entirely new "kinds" of imaging, including imaging with photons that never interacted with the object of interest and imaging with less than one photon.

Research Concentration Areas: Areas of interest include, but are not limited to: (1) Experimental production and detection of novel and/or high-flux entangled and other tailored states of quantum systems; (2) Investigation of interferometric schemes of imaging, including imaging without interaction; (3) Exploration of "ghost" imaging, in which parts of entangled states that never interacted with an object can provide the image; (4) Information-theoretic exploration of imaging and how to reconstruct information from both the interferometric and entanglement schemes; (5) Material and device studies leading to an instrument for implementation of these schemes as required by long-range applications.

Impact: Realization of quantum imaging would push measurement and imaging to fundamental limits. It would enable fundamentally new ways of imaging. If successful these include stealthy (i.e., covert) and counter-stealth imaging modes. (The latter includes the ability to image stealthy objects that absorb or otherwise deflect the interrogating photons, including seeing in harsh environments.) Related is remote sensing. Such nonlocal image creation might provide secure communication of multidimensional data. Other impacts would be on non-destructive imaging, and possibly ultrasensitive ways to detect but avoid triggering munitions/mines. Sub-wavelength imaging schemes would also impact on lithography.

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FY05 MURI Topic #6
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ADVANCEMENT OF MAGNETIC RESONANCE FORCE MICROSCOPY TO SINGLE NUCLEAR SPIN DETECTION

Background: Magnetic resonance force microscopy represents a revolutionary new technique for direct nondestructive imaging of 3D atomic structure in individual molecules, nanostructures and inhomogeneous solids. The technique extends the capability of magnetic resonance imaging by combining it with the high sensitivity and spatial resolution achieved in scanning probe microscopy. Recently, single electronic spin detection has been demonstrated, but there is potential to go much further. The goal of this program is to advance the science to the point where detection of individual nuclear magnetic moments can be accomplished, and three-dimensional mapping of their position in inhomogeneous samples can be demonstrated with atomic spatial resolution. The focus of this program is to explore the fundamental physics needed to achieve these goals as well as to identify innovation breakthroughs that will advance the state of the art to the level of single proton sensitivity. This will necessitate increased understanding of relevant physics and quantum mechanics of spin behavior, including spin-cantilever tip interactions, spin-state manipulation, and spin decoherency mechanisms in the presence of the large magnetic gradients required to achieve the desired level of resolution. Major engineering advances are also required to understand and manipulate sample-probe interactions, which constrain cantilever design, cantilever attonewton force reconciliation, and magnetic tip fabrication and integration with the cantilever. The improved innovations will in turn drive experimental protocols, signal processing approaches and data collection techniques suitable for achieving the high signal-to-noise ratio and rapid signal retrieval times also required to achieve the desired resolution. Proposals shall include the construction and demonstration of a proof of concept system. Successful advancement of the state of the art will broadly impact the sciences, and in particular, greatly accelerate advancements in the fields of multifunctional materials, nanoscience and biotechnology at a spatial resolution, which enables characterization in the nano regime.

Objective: Conduct basic research that facilitates the development of a magnetic resonance force microscope (MRFM) capable of in-situ detection of individual nuclear magnetic moments and three-dimensional mapping of their position with atomic resolution.

Research Concentration Areas: Conduct basic research in the following areas to establish the science base and infrastructure needed to advance the state-of-the-art in magnetic resonance force microscopy. The emphasis is on better understanding the fundamental phenomena that will ultimately determine detection limits and times, and then developing experimental breakthroughs that will permit realization of the goal of single nuclear spin detection. This research should be basic in nature, but tightly focused on achieving the goals of the program. Specific research areas include, but are not limited to: 1) Fundamental investigations of the relevant physics and quantum mechanics of spin behavior (electron and nuclear) in these systems, including spin-cantilever tip interactions, spin-state manipulation, and spin decoherency mechanisms in the presence of large magnetic gradients, that are needed to make hardware design decisions. 2) Experimental development and demonstration that address needs in cantilever design, cantilever position monitoring and attonewton force reconciliation, magnetic tip fabrication and integration with the cantilever, rf excitation, and heat management/temperature control at cryogenic temperatures. 3) Experimental protocols, signal processing approaches and data collection techniques suitable for achieving a high signal-to-noise ratio and rapid signal retrieval times. 4) Theoretical development and demonstration needed for system control, data manipulation and 3D image reconstruction.

Impact: Magnetic resonance force microscopy offers a revolutionary new capability for mapping the composition and structure of molecules or nanostructures with atomic resolution. Even modest improvements will have broad commercial / military utility and will significantly impact advanced semiconductor device research (e.g. individual impurity and defect characterization), nanoscience, single-molecule analytical chemistry, biotechnology, infectious disease research, and solid state/quantum physics research. In addition, MRFM can enable spin state manipulation, which could eventually lead to spin-based quantum computers, or new breakthroughs in the field of magnetic memory and spintronics (spin-based electronics).

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FY05 MURI Topic #7
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MATERIAL ENGINEERING OF LATTICE-MISMATCHED SEMICONDUCTOR SYSTEMS

Background: Today, nearly all commercial and defense electronics are based on the epitaxial growth of semiconductor layers, which are lattice matched to one of a very few available bulk substrate materials in order to obtain the best material and device performance. The result is a partitioned technology where most digital computing is performed on Si, and most rf-frequency and optical sources are based on III-V (and II-VI) material systems grown on either GaAs or InP substrates. In addition, DoD relies heavily on infrared detection systems based on HgCdTe growth on CdZnTe substrates. This partitioning of the industry poses major obstacles to device integration, and greatly restricts the choice of material systems that are candidates for bandgap engineering of future devices. However, the recent introduction of strained-Si CMOS and 'metamorphic' InGaAs buffer layers in pHEMT devices testifies to the advent of a new age. The ability to grow high quality lattice-mismatched systems, both relaxed and strained, combined with recent advances in the low-temperature transfer of relaxed epitaxial layers provides the basis for integrating virtually any combination of material systems. The realization of this capability, especially on Si or SOI substrates, could significantly enhance the overall performance and reduce future costs of DoD electronic systems.

Objective: Develop the technologies needed to engineer new device structures based on the combination of growth and transfer of lattice mismatched semiconductor layers, and establish the infrastructure needed to mix and match semiconductor systems across the entire lattice-constant range spanning from Si to HgCdTe.

Research Concentration Areas: Basic research in the following areas is required to establish the science base and infrastructure needed to facilitate the commercial realization of lattice-mismatched electronics. This research should be basic in nature, but be tightly focused on a few materials systems that offer the greatest technological payoff. Specific research should include, but need not be limited to the following. 1) Heteroepitaxial growth studies should be pursued to identify optimal approaches for dealing with defects, strain and phase distribution in these systems. In particular, techniques for fully relaxing the films and engineering the defect structures (e.g. introducing appropriate misfit dislocation arrays, effectively utilizing point defect concentrations, and minimizing threading dislocations and interface traps densities) will be critical. 2) Improved techniques for the liftoff, transfer and bonding of semiconductor layers (or mesas) onto mismatched substrates should be pursued. These layers may be utilized either as alternative substrates for further growth or as active layers in a device structure. Issues related to strain, interface quality, carrier transport, thermal management, interconnects and lifetime, as they would affect final device performance, should be addressed. 3) Novel device structures that build on the new breakthroughs in materials integration should be fabricated, and their structural, electronic, frequency response and thermal properties should be fully characterized. 4) Finally, prototype devices should be fabricated and tested. The expectation is that integration of functions onto Si and SOI substrates will be greatly expanded, and that much greater flexibility in device design will be realized, e.g. the realization of transistors with higher mobility channels, on-chip r.f and optoelectronic elements, light emitters and detectors tuned to any desired wavelength, and higher efficiency solar cells.

Impact: The research is expected to greatly expand the material systems available for future design of electronic devices, and vastly improve our ability to engineer new devices to meet future DoD needs. This research should greatly increase the level of integration that can be achieved in the future, as well as open up new opportunities for enhancing device performance and cutting costs. For DoD the research will provide system designers with new options to enable major performance gains in the areas of high-speed data processing, improved target detection/ recognition, and improved battlefield communications. In addition, the ability to conduct wafer-scale integration of high performance infrared detector arrays directly onto Si read-out electronics would dramatically reduce the cost of IR focal plane arrays and provide a corresponding increase in the level of their deployment. For the electronics industry, the ability to integrate across semiconductor groups will provide an alternative to scaling as a means of achieving future performance gains in such areas as high performance computing, and mobile communications.

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FY05 MURI Topic #8
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ENABLING SCIENCE FOR FUTURE FORCE INSENSITIVE MUNITIONS

Background: The Army's Future Force requirements (lighter weight platforms, increased range of engagement, and lethality, reduced logistics burden) make munitions safety and survivability very difficult to achieve. The shift towards smaller, lighter platforms concurrent with worldwide operational deployments also increases the survivability risk of munitions by attack from foreign hostile nations, terrorists and accidents. The current insensitive munitions (IM) science database and the capability to provide the Future Force with technologies to simultaneously meet performance goals while achieving safety and survivability is not up to the task. There is no focused DoD/DOE basic research IM program to provide data that will feed to systems engineering programs for the development of IM compliant weapons systems. The motivation of this program is provide the basic research that is required for IM technology enablement. In particular, energetic materials are the key munition components that affect the survivability of a weapons platform and storage. There are many basic research obstacles that must be overcome. For energetic materials, these include the development of models and simulations (M&S) describing the physics of dynamical interactions of molecules in the condensed phase. New analyses are needed that incorporate the physics of the earliest interactions between the threat and the energetic material that ultimately lead to initiation and reaction propagation. Such analyses must be based upon experimental results at the atomic or nearly atomic (e.g. molecular, nanometer) scale. Elements of this program include energetic materials condensed phase energy releasing processes, shock initiation mechanisms, energy partitioning and distribution during fast chemical processes, chemical and physical mechanisms, defects/voids, crystal structure morphology (e.g., IRDX), and mechanical properties. This understanding will enable the design of new insensitive munitions, based on conventional, composite materials as well as emerging nano-structured materials.

Objective: The objective is to develop a new understanding of energy releasing mechanisms under various stresses (shock, impact, thermal), specifically, initiation and other processes that lead to detonation and to develop the multiple time- and length-scale models for the prediction of the sensitivity of energetic materials.

Research Concentration Areas: This topic seeks to capitalize on recent advances in computational techniques for addressing atomistic/molecular/nano-scale dynamic processes and high spatial and temporal resolution experimental methods. Areas of concentration of this MURI include (1) development and utilization of state-of-the-art modeling and simulation techniques to provide accurate descriptions of the physics of dynamical interactions of reacting energetic materials in the condensed phase; (2) utilization of advanced instrumentation (e.g. ultra fast lasers, atomic force devices, environmental scanning electron microscopy) to experimentally map-out in real-time (at the atomic and molecular level) the energy releasing chemical reactions and energy partitioning to chemical intermediates and products; (3) quantification of the initiation susceptibility of energetic materials to impact, shock, thermal processes, at time scales from sub-nanosecond to seconds, including the role of crystal defects, voids, dislocations on these processes; (4) modeling and simulation of microscale and mesoscale processes occurring during interactions with energetic materials, incorporating fracture, frictional effects, jetting & viscous heating at material interfaces, void collapse and adiabatic gas compression, and phonon pileup at dislocations; (5) develop a multi-scale modeling and simulation capability, coupling atomistic/molecular with microscale & mesoscale descriptions.

Impact: This work will provide basic research supporting DOD Insensitive Munitions initiatives to provide the following technology payoffs: reduced hazard classification, increased flexibility for stored munitions, increased platform survivability and increased readiness. Currently, few weapon systems fully meet IM requirements. This program will provide a revitalization of the enabling basic research that is required to overcome these obstacles.

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FY05 MURI Topic #9
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DETECTION AND SENSING BELOW THE SHOT NOISE LIMIT

Background: Recent advances in quantum information and coherent matter wave physics have shown the possibility of performing interferometric measurements below the "shot noise" limit, i.e. with a sensitivity that is not limited by the intrinsic statistical fluctuations of field amplitudes. Ideally, such measurements would attain the fundamental "Heisenberg limit," which expresses the uncertainty principle between amplitude and phase of the field being measured. Shot noise-limited measurements can resolve phase differences proportional to the inverse square root of field amplitude, whereas Heisenberg-limited phase differences scale inversely with amplitude. Heisenberg-limited interferometry could lead to several orders of magnitude improvement in the stability of atomic frequency standards, and in the sensitivity of any sensor that is based on interferometric determinations of phase, such as optical or matter-wave gyroscopes, accelerometers, gravity gradiometers, and magnetometers. In practice, such measurements require the preparation and manipulation of nonclassical states of the fields to be measured. Emerging optimism about the realistic prospects of Heisenberg-limited measurements derives from breakthroughs in quantum state preparation, in particular the production of entangled and squeezed states of many-particle systems. These developments have been driven by research on quantum computing – a far distant goal, which will require strong entanglement of many particles. However, relatively weak entanglement would suffice to implement Heisenberg measurements in useful systems. Thus we believe the time is ripe to harvest the results of advances in quantum information research and to deploy them towards the more near-term but still ambitious goal of sub-shot noise sensors and detectors.

Objective: To develop a range of capabilities for preparation and detection of nonclassical states of light and atoms, suitable for use in interferometry. Such capabilities include deterministic preparation of spin-squeezed atomic ensembles, development of quantum nondemolition measurement techniques, quantum parameter estimation, real-time quantum feedback control, and entanglement of large numbers of atoms. A characteristic MURI goal for a three-year period might be the development of a laboratory-scale Heisenberg-limited instrument, such as an atomic magnetometer or frequency standard. A goal for subsequent work could be the production of a fieldable instrument. Other goals might include the identification of Heisenberg-limited measurements in alternative systems, such as electric circuits, that could lead to fundamental improvements in electrometry or magnetometry.

Research Concentration Areas: Areas of interest include, but are not limited to, the following: (1) Information-theoretic exploration of Heisenberg-limited interferometry schemes, focusing on prospects for practical implementation with photons, ultracold atoms, trapped ions, or other quantum systems such as Josephson junction arrays; (2) Experimental production of squeezed and entangled states of quantum systems; (3) Development of techniques for quantum feedback and control of decoherence, and quantitative theory of the dynamics of relevant quantum systems; (4) Material and device studies leading to chip-scale implementation of atom or photon interferometry as required by long-range applications.

Impact: Realization of Heisenberg-limited measurements would push phase interferometry to its fundamental limits. It would provide the ultimate contribution of basic science to the implementation of a given measurement process, and thus relegate sensor and detector optimization to engineering. Several orders of magnitude improvement are projected in sensitivity and accuracy of frequency standards, magnetometers, and inertial sensors.

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FY05 MURI Topic #10
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NOVEL DIELECTRIC MATERIALS FOR HIGH PULSED POWER CAPACITORS

Background: The Navy requires more efficient energy storage and transfer media to enable future high pulse power electric naval applications. Capacitive technologies are anticipated to meet a significant portion of this need, but existing storage materials and formats are not adequately energy dense and continue to rely on established materials. Current foil and metallized film high pulse power capacitors are still primarily designed using generic polymer dielectric materials such as Kraft paper and polypropylene due to the high dielectric breakdown voltages and low costs (including processing) of these materials. Ceramic materials are not currently used in these applications due to mechanical failure (i.e., cracking) under stress. Scalable capacitor technologies with an order of magnitude or greater improvement in storage capacities (to achieve~30 J/cc at the materials level and ~10 J/cc at the device level), rapid discharge capability (milli- to microsecond discharge rates), and stability over thousands of cycles would have a significant impact on the size, weight and performance of future pulse power electrical systems.

Ceramic materials can exhibit extremely high dielectric constants of 1,000-20,000 (and thus high storage densities), but suffer from low breakdown strengths and non-benign failure modes that currently prevent their use in high pulse power applications. Recent advances suggest that controlling domain sizes and "designing" the nature of the grain boundaries are pathways to increase breakdown strengths. Polymeric materials are processable, low cost, and have high breakdown strengths, but typically have low dielectric constants in the 3-5 range, thus limiting their storage capability. Over the past decade the semiconducting properties of organic and polymeric materials have been enhanced, in some cases by two orders of magnitude, through an understanding of molecular polarizability and the behavior of delocalized electrons--knowledge and approaches that have yet to be applied to the design of novel dielectric materials. Additionally, new synthesis tools have been developed to allow facile self assembly of complex polymeric, ceramic, and hybrid structures. It should now be possible to design highly processable, low cost, self assembled composite or nanostructured dielectric materials that offer significant increases in storage density for film capacitors for high pulsed power applications. A multidisciplinary approach is required since the polymer and ceramic dielectric communities have previously worked independently to address the shortcomings of their distinct materials approaches, while a close working relationship will be required to develop practical hybrid systems that integrate the high dielectric constants of ceramics and the high breakdown strengths of polymers with storage advances beyond simple empirical approaches.

Objective: To provide the scientific foundation for an order of magnitude or greater increase in the performance of high energy/high pulse discharge dielectric capacitors over the current state-of-the-art. An interdisciplinary approach that focuses on the chemistry, physics, and materials science of the dielectric layer is needed to understand behavior in current materials (i.e., dielectric breakdown mechanisms, which are not understood) and to develop synthetic and characterization methodologies to discover new materials that possess the required high breakdown strength, high dielectric constant (over the kilohertz to megahertz frequency range), low dielectric losses, and processability for improved storage.

Research Concentration Areas: Areas of interest include, but are not limited to, the following: (1) Understanding and predicting the dielectric response and breakdown of composite or nanostructured films; (2) The design and synthesis of high dielectric, processable materials; (3) High dielectric organic resins, organic/inorganic composite dielectrics, processable inorganic dielectric films; (4) Design and characterization of the capacitor performance, lifetime, graceful failure modes; (5) Theoretical prediction and simulation of dielectric performance.

Impact: Future Naval Electric platforms will require significant power for non-propulsive needs. The most significant challenge to enabling these future platforms is high energy/high pulse power storage devices. Capacitors are a promising energy storage solution for these applications since they have no moving parts, can be designed with benign failure modes, and are highly modular, enabling the design and manufacture of appropriately sized capacitor banks. An order of magnitude improvement in capacitor storage density would provide the enabling technology for practical implementation of high energy weapons in the Fleet. Improved storage densities would also impact other pulse power applications, including transient current filtering in distributed power systems, data processing, and communications.

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FY05 MURI Topic #11
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MULTI-ENERGY PROCESSING SCIENCE

Background: The performance demands of future DoD systems continue to increase with requirements for faster, more agile, longer range, stealthier and more durable characteristics. These requirements in turn place stringent performance demands on future material systems. They need to be stiffer, tougher, light weight, capable of operating in high temperatures and corrosive environments, with low friction and wear, and they must be affordable. Meeting such demands will require investments in new technologies that can economically synthesize and/or process materials with extraordinary properties.

A revolutionary new concept based on multi-energy processing has the potential to overcome many of the limitations of conventional processing methodologies by depositing energy only where it is needed. By having multiple energy sources (such as various lasers or microwave sources), with each one tuned to a specific electronic, vibration, or other excitation state of the system, only a targeted reaction between specific components of the system can be initiated. The possibility then exists of synthesizing new materials at room temperature, in an open atmosphere, and without contaminants, by-products or side reactions.

Objective: To generate understanding of the phenomena involved in Multi Energy Processing of materials. Specifically, this will require understanding what the required multi energy process parameters (such as number of lasers, their wavelengths, energy densities, pulse duration, repetition rates, sequence, microwave sources and other parameters) should be for growing a specific coating onto a substrate. To narrow the effort, only coatings that enhance the thermo-mechanical properties of the substrate (coatings such as chromia, zirconia, diamond, CBN onto substrates such as WC, steel, Ni, Al or other DoD relevant combinations) will be used as part of the research. The ultimate goal of this effort is to develop a new "Materials Processing Science" based on the use of multiple energy sources that will allow us to synthesize new materials for DoD applications with extraordinary properties that can be applied on site, in an open atmosphere and at a reduced cost.

Research Concentration Area: This project is multidisciplinary in nature requiring knowledge in lasers, optics, physics, chemistry and material sciences. Areas of interest include, but are not limited to, the following (1) use of multiple laser beams for synthesis and processing of new materials (2) understanding the roles of each of the lasers on film growth and how to optimize the lasers relative to time of arrival, pulse duration, fluence and wavelength, (3) atomic and molecular level diagnostics in the gas and solid phases during multi laser processing, (4) basic physics and chemistry of plasma phase deposition during multi laser processing, (5) advanced laser assisted growth techniques and epitaxy science.

Impact*:* The possibility of depositing any thin film onto any substrate with extraordinary properties (such as diamond, boron nitride, chromium oxide and other ultrahard films) with a process that operates at room temperature and in an open atmosphere but nevertheless with a reduced degree of contamination could now be possible by the development of the science of multi-energy materials synthesis and processing. Materials that once required extremely high pressures, temperatures and controlled atmospheres to be synthesized might now be manufactured at room temperature and in an open atmosphere. This could open the way to a technological explosion of new materials with vastly improved mechanical, thermal, electrical (not addressed in this MURI), and optical (not addressed in this MURI) properties. This technology could also facilitate the repair of parts (that have experienced severe wear, corrosion or cracking) right in the field without major disassembly.

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FY05 MURI Topic #12
Submit white papers and proposals to the Office of Naval Research

REALTIME SENSING, PREDICTION, AND RESPONSE TO EVOLVING NONLINEAR WAVEFIELDS

Background: Though there have been substantial advances in sensing and measuring waves at sea and in the development of theoretical and computational prediction methods for the nonlinear interactions of waves (producing, for example, "rogue waves"), there remain important hurdles to fast and accurate near-term projection of a wavefield for realtime use in avoiding dangerous situations for a ship at sea. The leading commercial radar systems available for ships provide only average conditions, such as "sea-state" and the propagation direction of dominant waves. However, the interaction of high, steep waves can form transient conditions not predictable from averaged data; realtime data together with fast near-term prediction methods are needed to forecast imminent danger. Other applications would be the prediction of transient calm regions for launch or recovery of auxiliary vehicles and weapons. Advances have also been achieved in the prediction of ship motions in a seaway, but again, there remain hurdles to obtaining fast and accurate methods useful for realtime prediction and maneuvering. The methods would need to be embedded in a fast optimization scheme to determine the best trajectory; this also needs development for this particular type of application. Finally, control schemes are needed for ships and small craft which can respond continuously to transient commands without introducing instabilities in the complex, nonlinear maneuvering characteristics of many ships. The merging and interaction of four distinct sophisticated scientific disciplines is required to provide a significant leap forward in safety and performance of ships in a seaway.

Objective: The overall goal is an integrated approach to wave-sensing, prediction, and optimum response for safe and effective maneuvering of ships and smaller craft in a seaway. The research objectives implied by this goal include: Development of sensing techniques and processing algorithms for wave-measurement adequate for determining height, direction, and speed/wavelength of individual waves at sea; derivation of theoretical and computational methods for fast near-term prediction of an evolving wavefield given input data; development of fast prediction methods for nonlinear ship motions in a wavefield; formulation of fast optimization techniques for trajectories linked to control schemes for maneuvering. Each of these will require fundamental developments and subsequent formulation of implementable methods to be integrated with the others. The models and methods must also be demonstrated to work in real seastates with high wind conditions. Research Concentration Areas: New understanding and capabilities are required in four distinct but coordinated disciplines: (1) Realtime sensing techniques and processing algorithms for measurement of waves at sea; (2) Theoretical and computational methods for near-term prediction of waves and their nonlinear interactions given time-evolving input data; (3) Theoretical and computational techniques for the fast prediction of nonlinear ship motions given an evolving wavefield; (4) Optimization methods for trajectories linked to control schemes for maneuvering.

Disciplines: Successful proposals could involve investigators from the areas of oceanography, fluid mechanics/hydraulic engineering, remote sensing/radar physics and microscale environmental physics, nonlinear control theory/dynamics/mathematics, and naval architecture.

Recent progress in the creation of sophisticated new signal processing and control theoretic techniques in sensor and actuator systems distinct from ocean sciences applications may suggest effective approaches to transient condition analysis and response in the ocean. A goal of this MURI is to exploit these advances in an interdisciplinary fashion

Impact: A wide range of impacts would result from advances in the individual research areas of interest here. Wave measurement and prediction is important to oceanography, meteorology, and environmental studies as well as naval operations. Accurate prediction of ship motions can reduce the cost of ship design/testing and improve performance. New optimization and control schemes would find wide application. These are in addition to the particular targeted impact: Real-time intelligent maneuvering of ships and craft would increase safety and expand the envelope of weather-limited naval operations. Department of Defense Relevance: Clear beneficiaries of the MURI results would be the Navy for design of automated surface vessels and ship to ship transfer systems, the Army for problems related to offshore cargo handling for logistics, the Joint Logistics efforts, and Navy and Joint interests in novel sea basing concepts that will be critically dependent upon seakeeping in rough sea states.

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FY05 MURI Topic #13
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MATERIALS MANUFACTURING PROCESSES, INTERFACE CONTROL, AND RELIABILITY OF NANOSTRUCTURE-ENHANCED DEVICES FOR ENERGY CONVERSION AND REALIZATION OF HIGH PERFORMANCE SYSTEMS

Background and Description: Nanostructured materials offer exciting possibilities for the development of new and performance-enhanced technologies in a wide range of energy conversion applications from small to large scale, including thermal to electric energy conversion systems for power generation, electric to thermal heating and cooling systems, efficient high power lasers, and high temperature/high field permanent magnets for advanced generators and motors. These technology advances can only be realized if the nanostructured materials are designed, processed, and integrated into components and devices with careful consideration of the materials property/performance characteristics from initial synthesis/growth/assembly through processing, assembly, and ultimately, at operating conditions. High throughput analysis and monitoring of materials nanostructure and related enhanced properties is an integral component to the advancement of the materials and device technologies.

Many research issues associated with manufacturing at the nanoscale have recently been identified in the Chemical Industry R&D Roadmap for Nanomaterials by Design: From Fundamentals to Function." Addressing these issues, of course, will have implications for technologies much broader than those outlined above, from the micro to the macro scale. Understanding the synthesis, processing, and manufacturing conditions that produce the optimal nanostructure for highest efficiency performance is key to transitioning nanostructured materials into reliable technology. Retention or further enhancement of the performance advantages in the scalable production and processing of nanostructured materials, in their assembly into devices, and under possibly extreme operating conditions requires a detailed understanding of the kinetics and thermodynamics of the chemical/materials system, including compositional stability, phase stability, crystallographic orientation relative to the bulk, microstructure and the mechanical, electrical, optical, magnetic and thermal properties, stability, and reliability. Compatibility and reliability of interfaces, as well as failure mechanisms at operating conditions are also critical issues.

Objectives: To develop process technologies that will enable the manufacture of nanostructured bulk materials that retain and/or improve the nanostructural performance enhancements and reliability of the material for incorporation into operational modules for application into cooling/heating modules, thermal to electric power generation devices, advanced high power lasing materials, and/or advanced permanent magnets. Considerations include nanostructure design and control (phase composition, grain size, crystallographic orientation), mechanical properties (brittleness, ductility, et al.), application oriented property control (i.e., thermal, electrical, optical, and magnetic field), and interface design and control at the nanoscale (i.e., within the bulk material) and macroscale (e.g., electrical and thermal contacts for device integration). To develop cost-effective fabrication methods to produce large quantities of nanoscale-enhanced materials and devices for energy conversion related systems (power generation, advanced lasers, small high performance permanent magnets) of interest to the Department of Defense. To identify and develop approaches to address significant reliability issues in the bulk materials or devices based on nanoscale components.

Research Concentration Areas: Areas of interest include, but are not limited to, the following: (1) identification of new compositions and materials of interest for energy conversion (i.e. thermal to electric, electric to coherent light, magnetic to electric, electric to thermal) whose bulk properties are enhanced by nanoscale structures; (2) development of scalable processing technologies to maintain nanoscale-enhanced performance for bulk materials; (3) development and/or novel utilization of high throughput nanostructure characterization and analysis tools; (4) development of models and simulations focusing on chemical, electrical, optical, magnetic, thermal, and/or mechanical compatibility and reliability. Fabrication approaches and manufacturing practices that emphasize materials and processing safety and that will have minimum environmental impact are encouraged.

Impact: Innovative and scalable nanostructured materials processing/manufacturing technologies for the development of highly efficient thermal energy conversion and control devices will lead to revolutionary new capability and performance in a wide variety of Defense systems from undersea to space-based applications. Advances in understanding of the process-related and optimized performance, reliability, and failure mechanisms of the integrated nanostructured materials, including the interfacial science and engineering of contacts to the nanostructured material, will impact a broad array of high performance Defense device applications, for example, new solid state thermal conversion systems for primary or secondary power generation and cooling for high performance electronic and photonic devices. New magnetic materials capable of operation at high temperature will lead to advances in motor design, generator technology, and energy storage systems capable of addressing the future electric Naval force. Advances in lasing materials may ultimately lead to advanced weapons systems, lidar, guide stars, and range finders with reduced power requirements. The availability of high throughput manufacturing processes for nanostructured materials, as well as high throughput metrology tools, and performance models. It is anticipated that miniaturization will lead to systems with superior performance characteristics and which will lighten warfighters' burden.

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FY05 MURI Topic #14
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GAN BASED MM-WAVE SOURCES

Background: The move to network centric warfare places extreme requirements on the RF sensors in the battlespace. Wide bandgap semiconductor technology has enhanced the capability of active microwave array radars, however these materials can also be exploited for mm-wave solid state sources, if there are further advances in the fundamental understanding of the underlying materials and the device physics. At mm-wave frequencies GaN based devices can deliver as much as a 10-fold increase in output power, as compared to competing solid state solutions. Moreover, for communications systems this added power capability can be traded-off for superior linearity or efficiency. Improved linearity allows more data to be transmitted over a wireless link by exploiting advanced coding schemes. Extending this capability to the mm-wave region will give an order-of-magnitude increase in signal bandwidth. An AlGaN/GaN High Electron Mobility Transistor (HEMT) with an f_t of 121 GHz has been demonstrated, and extrapolations from this work suggest that an f_t of 200 GHz is possible if the predicted electron transport can be realized. GaN based devices have been extensively studied at frequencies up to 20 GHz but only limited work has been done at mm-wave, mostly from 26 to 30 GHz. To realize the mm-wave potential of the GaN technology at frequencies of 60 GHz and above, and expand our general understanding of the fundamental issues limiting the development of mm-wave solid-state (SS) power sources, a variety of interdisciplinary, fundamental research issues need to be studied. In particular: the impact of hot-phonons on the frequency response of HEMT devices, bandgap engineering in the context of mm-wave applications, novel insulators for improved passivation and reduced impact on frequency response, device and circuit development to allow for the extension of the frequency response of field-plated devices, and innovative power combining approaches appropriate for wide bandgap, high-voltage devices and circuits.

Objective: This program will explore the fundamental issues impacting the use of GaN based electronic devices in mm-wave applications. The goal is to resolve these issues in a manner that facilitates the use of GaN based devices at frequencies of 44 GHz and above.

Research Concentration Areas: Areas of interest include, but are not limited to, the following:

Solid State Physics: (1) Characterization and minimization of the impact of hot phonon effects (2) Fundamental studies of the impact of materials, bandgap engineering and device design on the peak electron velocity in the channel, charge control and mobility.

Materials Science: (3) The development of novel insulators for passivation that will minimize the parasitic capacitances that impact frequency response. (4) The use of novel structures such as superlattices for both supply- and confinement- layers for enhanced performance.

Electrical Engineering: (5) The development and implementation of physics based modeling suitable for the prediction of mm-wave performance. (6) Studies of novel device structures and circuits that will allow the extension of field plates to mm-wave frequencies. (7) Studies of innovative power combining approaches that make use of the unique properties of the GaN

materials system and (8) Approaches to on-chip integration of control components and radiating elements appropriate for the utilization of the GaN technology at mm-wave frequencies.
Impact: This work will significantly increase the power available from SS sources at mm-wave and as such will have an across the board impact on Radar, Communications systems and Electronic Warfare (EW) in particular Electronic Attack (EA).

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FY05 MURI Topic #15
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EXPLOITATION OF THE COHERENT STRUCTURES IN RIVER AND ESTUARINE FLOWS FOR DOD OPERATIONS IN DENIED AREAS

Background: Observations of river and estuaries by photography, radar, video and hyperspectral remote sensors clearly show a rich cascade of flow structures near the surface of the water column. These include fronts where flows merge, vortices shed from instabilities along these fronts or by flow along the side or bottom boundaries, cascades of eddies related to the breakdown of the larger structures, and turbulent swirls at smaller scale. These features often appear coherent in time and space and are advected with the overall flow. Coherent structures are visible because of transported sediment, debris or biota that appear as color or reflectors, and in some cases the roughness of the flow itself provides backscatter that is modulated by the flow patterns. These features have not been exploited as a source of information and used to constrain river/estuarine model nowcasts for tactical use or assimilated as a basis for forecasts. In denied areas (for military operation), this information may allow for a dramatic impact on DoD operations planning and execution.

The scientific problem is made complex because of the range of time and space scales of interest and the modification of the flow regime introduced by temperature, salinity and density differences; variations in bed materials; and sources of debris, detritus and biological activity.

Objective: To understand how the space-time coherent structures in the flow field relate to the underlying physical characteristics of the river/estuarine system. Additionally the program will investigate which physical features and processes remote sensors actually observe as well as providing information on the averaging scales. The overall goal of the research is a combination of prediction schemes coupled with observing systems that exploit the information inherent in the remotely sensed coherent structures to aid in planning operations by DoD.

Research Concentration Areas: Areas of interest include, but are not limited to, the following:

- Remote sensing imaging systems that can provide adequate spatial and temporal coverage in field studies to provide fundamental observations of the coherent structures
- Use of nonlinear flow dynamics and chaos theory that may be helpful in identifying and tracking coherent structures
- Development of Large Eddy Simulation (LES) and Direct Numerical Simulation Techniques (DNS) for detail simulation of the flow structures
- Development of data assimilative 2 and 3 dimensional flow models for synoptic to meso-scale flow prediction
- Development of concepts for mini-UAV, AUV sensors to provide information

Impact: DoD forces often ford, navigate or swim in rivers and estuaries during key operations. Often they must do this either without reliable information on currents speed, temperature, or clarity and how these vary in time and along/across the channel or with depth. The operations can also be affected by the quality of the water (biologic, disease bearing waste, toxic chemicals) which can affect the ability of the warfighter to perform the mission as well as concerns for their long term health. Riverine and estuarine environmental information is lacking for a variety of circumstances: denied territory, insufficient information on which to base flow forecasts, rapid changes in conditions. The ability to remotely sense and accurately forecast these parameters would impact the planning and remove a major obstacle to operations in the denied areas.

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FY05 MURI Topic #16
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MAGNETIC DETECTION SCIENCE AND TECHNOLOGY

Background: The detection of vector magnetic fields in a noisy environment involves basic physics, materials science, device invention and design, and signal processing to separate and discriminate signal from noise. Ultimately, a device must deal with trade-offs among resolution, power requirements, cost, size, simplicity of use, and lifetime. In the last decade there has been an explosion in discovery of new magnetic sensing techniques that are based on materials and structures that in principle may be produced using microelectronic processing methods. These new sensing techniques open opportunities to use magnetic sensors in innovative ways for evolving Defense missions within Forcenet scenarios and in littoral regions. Sensors may be used as arrays or in multi-sensor combinations and directly integrated with signal processing electronics to improve sensitivity, signal to noise, directionality, and selectivity (canceling or subtracting signals from sensor platform).

Objective: The objective of this program is to develop systems that exploit novel magnetic sensing techniques to detect ac and dc magnetic fields approaching the pico-tesla per root hertz sensitivity. This may require combining multiple sensors, and different types or sensitivities of sensors into a single system. Ideas from animal geomagnetic sensory detection may be of value. There is also an interest in being able to detect the electric field signal in extremely low frequency electromagnetic signals. The type of physical measurement will help determine the optimal signal processing algorithm to extract signal from noise. It will require sophisticated analysis of fields detected as a function of time, direction, frequency, and strength. The ultimate goal of this program will be to produce small, low cost, low power consumption magnetic (and electric) sensors for Defense applications.

Research Concentration Areas: Research should include novel materials (e.g. 100% spin polarized "half metals"), novel structures (e.g. flux multipliers), innovative devices (e.g. spin polarized transistors), and fundamental understanding of the interaction of magnetic fields with these materials, structures, and devices. Magnetic sensor technologies to be considered include, but are not limited to, Giant Magnetoresistance (GMR), Spin-Dependent Tunneling, Giant Magnetoimpedance, Microfabricated Fluxgate, SQUIDs, Magnetostrictive-Piezoelectric, and optoelectronic approaches exploiting magneto-optical materials and coated fibers. Innovative approaches to electric field sensing may also be included. Calculating the nonlinear dynamical responses of devices to improve sensor performance (e.g. coupling fluxgate magnetometers) can also allow for exploiting lower power operating regimes.

Impact: Inexpensive, low power, reliable, sensitive magnetic field detectors can be deployed to provide sustained surveillance of the ocean to detect submarines and certain types of mines. The sensors may be at the ocean surface, bottom-mounted, on autonomous underwater vehicles or airborne. Defense mission applications include submarine and surface ship detection and tracking, mine hunting, weapons detection, underwater surveillance carried out by unmanned vehicles, and ground incursion sensors, including in the beach/surf zone.

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FY05 MURI Topic #17
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REVOLUTIONARY APPROACHES TO HYPERSONIC MATERIALS

Background: Hypersonic flight is an elusive goal, requiring propulsion and structural components able to withstand temperatures in excess of 2500ºC for sustained periods. Propulsion systems for enhanced hypersonic capability remain materials-limited. The challenge is developing the required materials within practical time and cost constraints. This will require revolutionary methodologies to design and demonstrate novel robust materials with predictable, controlled behavior.

Capabilities to dramatically reduce the time-to-system by guiding and reducing the iteration of important experiments while increasing confidence in material parameters have been initiated and are showing promise for distinct materials systems. Significant progress has been shown in concentrated efforts such as DARPA's Accelerated Insertion of Materials, AFOSR's MEANS: Materials Engineering for Affordable New Systems and ONR's Naval Materials by Design. Such concepts are based on strong fundamental knowledge of thermodynamics and kinetics of phase stability and microstructural evolution, and on physics of deformation and failure. The application of first principles calculations and linking of predictive models to handle phenomena from the atomic to the macroscopic can be pursued in concert with the development of constitutive models and the design of experiments to populate and validate them. Exploitation of such understanding may be extended to control reaction paths in order to pre-select desirable phases, to form inherently self-healing coatings, or to design for damage mitigation. Complimenting theoretical advancements, experiments themselves may now be accelerated through the application of combinatorial synthesis techniques for the rapid production of crystalline specimens or through incisive, targeted testing techniques that explore individual microstructural constituents of interest.

Research is needed to build upon emerging theoretical and experimental methods and create revolutionary fabrication processes to meet the materials challenges which will be enabling for hypersonic structures and propulsion. This requires researching and quantitatively describing the critical fundamental properties of materials capable of operating in severe environments and tailoring emerging tools and methodologies for design, prediction, control and demonstration of material performance.

Objective: To apply new theoretical approaches which will revolutionize the design, development and confident exploitation of light weight, structural materials systems capable of successful operation in hypersonic environments.

Research Concentration Areas: This effort may focus on one or several appropriate materials systems: ceramic composites, intermetallics, refractory materials, carbon-carbon composites, etc. For all systems emphasis is to be placed on developing and quantitatively defining the basic phenomena that determine chemical and mechanical stability and performance; on developing the methodologies required to enable rapid design and demonstration of optimized materials systems; and ultimately, demonstrating materials systems that meet the objective.

Impact: Realization of the objective described above will allow the safe, confident design of materials systems critical for proposed hypersonic vehicles and other systems envisioned for future DOD (e.g. National Aerospace Initiative) applications.

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FY05 MURI Topic #18
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RADICALLY NEW APPROACHES FOR ROBUST SPEECH-TO-TEXT

Background: Machine understanding of natural human speech has been a key goal of the Department of Defense for a long time. Robust, accurate, automatic transcription is a necessary prerequisite, and transcription of conversations is important for innumerable military applications, from monitoring terrorist activity to team training, to accident investigation. Although there have been great strides in recent years, the goal is far from met. Current off-the-shelf and industry systems are now commercially feasible for circumscribed applications (e.g., telephone answering and limited voice commands) but are unacceptable for all but a few Defense applications. The vast majority of recent work on speech transcription is extending and improving the Hidden Markov Model (HMM) approaches that have been developed over 30 years. Such efforts can only produce small incremental improvements; they cannot achieve the dramatic reductions in error rates required for effective speech understanding in real world situations. Speech scientists and scientific linguists know a great deal about spoken language, and this knowledge is ripe for exploitation. One reason these insights have not been well utilized is that these disciplines have mostly worked independently and have not teamed with mathematicians and engineers. A serious multidisciplinary effort fostering the use of radically novel approaches is needed to put the research on a whole new path. Several recent approaches, such as tracking prosodic information (sentence level, rather than phoneme level), modeling human speech production and perception, and generally incorporating multiple time-frequency scales, have shown considerable promise. However, short-term goals and practical considerations, such as high start-up costs, tend to push such innovations into add-ons to existing approaches rather than towards developing entirely new systems based on these new insights. Recent scientific advances in combination with the availability of vastly expanded computational resources and very large speech data bases make the time ripe for a major change in the underlying technology. The improved error rates and greater language independence of the ensuing speech recognition technology will also be a huge step forward for speech-to-speech translation systems that are being actively pursued by the Army, DARPA, and ONR.

Objective: To develop new speech recognition systems based on fundamentally new methods (replacing current HMM approaches) for analyzing and converting natural conversational speech to text. It is probable, but not essential, that these techniques will incorporate recent advances in our understanding of human speech perception and production. The goal is to develop recognition methods that will be speaker, language, and vocabulary independent and robust against variations in speaking style, rate of speech, fluency, accent, subject matter, acoustic environment, microphone quality, and channel characteristics. The long-term goal is to have machines perform as well as people.

Research Concentration Areas: Achieving this very challenging objective requires strong interdisciplinary work. Advances in basic science, developing fundamentally new models and frameworks, plus creative combinations of approaches are all necessary. Successful technology will exploit the insights of linguists, speech scientists, mathematicians, and engineers; use multiple knowledge sources (including acoustic-phonetic features, prosodic cues, and linguistic structure); learn and improve from representative data (without extensive human annotation); and adapt dynamically to changes in speaker, topic, and environment. Computationally tractable models of human speech production and perception may be especially important.

Impact: Robust, accurate speech-to-text technology will enable a huge number of important Defense applications. These include transcriptions for a variety of applications, as well as truly natural, conversational interaction with machines (even in adverse environments); accurate detection, extraction, summarization, and translation of a wide range of audio sources; and ultimately true understanding of unconstrained speech. The productivity gains will be enormous; the benefits to warfighters, incalculable and huge.

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FY05 MURI Topic #19
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RADIATION EFFECTS ON EMERGING ELECTRONIC MATERIALS AND DEVICES

Background: General trends in the consumer electronics industry include the reduced scaling of device physical dimensions, increased levels of integration (more devices per chip) and low-voltage, low-power designs. These trends are forcing the electronics industry to adopt new materials, device designs, circuit topologies and processing technologies. Emerging changes include deep submicron device dimensions, new hi-K as well as low-K dielectrics, copper chip-level interconnects, multi-gated transistors and biaxially strained SiGe on silicon. These changes are being made with little or no attention to operational reliability under extreme environmental conditions, conditions not important for most commercial applications.

Driven by needs to increase performance, to contain cost and to avoid multi-billion research and development investments, the defense and commercial space industries usually adopt, with virtually no modifications, these advances in consumer electronics. The tradeoffs are compromised electronic system reliability and survivability in extreme space environments. A key aspect of the space environment is enhanced exposure to radiation sources, sources both natural and, potentially, man-made. To guide space system designers in the adoption or modification of new commercial electronics technologies, detailed knowledge is required of the suitability of each technology change to the stressful space environment, particularly radiation exposure.

Objectives: Fundamental research is required on the physical responses of designated emerging electronic materials, devices and designs to radiation exposure. Guided by and incorporating this understanding, improved processing, device and circuit design tools will be developed and made available to the space electronics industry.

Research Concentration Areas: Of principal interest are the impacts of radiation exposure on the key industry trends and changes described above: reduced device dimensions (< 0.10 μm); new low-K and high-K dielectric materials; high Z interconnect and contact materials (Cu, W); strained SiGe-Si structures and devices. Consideration of both digital and mixed-signal electronics is of interest. Other related trend issues may be addressed, but these are key to this topic.

Next generation or generation-after-next electronics devices are projected to incorporate dielectric and semiconductor layers consisting of only a few atomic layers in one or more dimensions. The attendant fluctuations in the parameters used to characterize radiation effects must be simulated, understood and incorporated into device design tools. Atomic-scale physical modeling is required for this task.

The strained SiGe-Si system is metastable and will be forced into a new equilibrium if excessive energy (such as large temperature cycles due to the space environment and ionizing radiation) is introduced. The resulting strain relaxation may produce threading dislocations or higher bulk and interface defect densities. First principles physics calculations of these effects (ideally three

dimensional) should be performed coupled with the study of designs that would mitigate or eliminate such degradations. Experimental verification of the models is necessary.
The radiation impacts to be studied should include both ionizing total dose and single event effects. The proposal should detail the access to suitable radiation sources. It is not required that the samples of study be produced within the MURI program. However, convincing plans must be presented as to the sources, suitability and availability of such samples to the MURI team. Interactions with industry and government - particularly defense - laboratories are strongly encouraged and should be detailed.

Impact: At this time, there is almost no federally sponsored university (or other) research in the effects of radiation on electronic materials and devices. This state of affairs parallels the status of rad hard foundries in the U.S. – there are two remaining and they survive on federal subsidies. At the same time, the DoD and the civil sector are increasingly dependent upon space-based technologies for crucial infrastructural capabilities. This university effort should point to those emerging electronic materials and technologies that can be usefully applied to electronics on space platforms.

Research Topic Chief: Dr. Gerald Witt, AFOSR, 703-696-8571, gerald.witt@afosr.af.mil

FY05 MURI Topic #20
Submit white papers and proposals to the Air Force Office of Scientific Research

EXTREME LIGHT MATERIAL-BASED DIAGNOSTICS

Background: Laser diagnostics are vital tools for research and development and are used to analyze and evaluate materials, study new materials, evaluate improved fuels, investigate advanced concepts for aerospace systems and their components, and aid the development and evaluation of design models. This topic will establish the science base needed to develop a new generation of extreme light material-based diagnostic tools, including appropriate sensors and lasers, with a revolutionary common source of hyperspectral radiation and fundamental particles. Recent developments in tabletop, ultrafast (pico to atto second pulse), ultraintense (GW to PW+) lasers (UULs) (referred to as Extreme Light, Sci. Am., May 2002) are driving a new multidisciplinary area of research stimulating new discoveries and insights into fundamental phenomena in physics, chemistry, materials, and engineering sciences. This topic will capitalize on the discovery that extreme light/target interactions can produce ultrafast, high-brightness, micron size sources of hyperspectral radiation from T-rays to gamma rays and highly directional beams of ultrafast particles such as electrons, protons, positrons, neutrons, and ions with energies of tens of MeV. The radiation and particles can be used as sources for unprecedented diagnostic techniques that have the potential of tracking in time and space the motion and geometry of atoms and molecules as they are subjected to stimuli such as mechanical and thermal stresses, and chemical reactions. Current x-ray and particle sources do not have the temporal resolution to resolve molecular dynamics. Also, current particle sources are large nuclear reactors, accelerators, or radioactive materials that are not readily available. Extreme light driven sources are produced by a tabletop laser and do not involve radioactive materials. This topic will establish the science base that will enable the development of revolutionary extreme light diagnostic tools to: develop new techniques for material characterization with unprecedented spatial and temporal resolution that would enable dynamic structural and chemical analysis on the nanoscale.

Research Objectives: This initiative is to establish the science base needed to develop a new revolutionary generation of extreme light material-based diagnostic tools with the appropriate sensors and lasers. The research objectives include understanding of immediate and longer-term extreme light-material interactions and modeling of material characteristics and response subjected to UUL. The team would develop new techniques for simultaneous structural and chemical analysis on unprecedented timescales. This multidisciplinary team should include expertise in laser source operation and development, sensors, molecular physics, material sciences, nanotechnology, chemistry, and mathematical modeling.

Research Concentration Areas: Areas of interest include: (1) an extreme light laser with pulse formats, wavelengths, average peak powers, etc., that can be adjusted to meet the requirements of a common source of ultrafast, high-brightness, micron size source of hyperspectral radiation and particles; (2) diagnostic techniques that take advantage of the pico and attosecond timescales of extreme light as well as the simultaneous high peak powers available that enable novel spectroscopic techniques; (3) target materials that, when interacted with extreme light under different conditions, will provide common source of radiation and particles; and (4) radiation and particle sensors that will meet the needs of the new generation of extreme light material-based diagnostics.

Impact: This research will provide new, revolutionary extreme light diagnostic tools for understanding of materials and processes where it is critical to understand chemical and structural interactions on short timescales and with atomic spatial resolution. These diagnostics tools are cross-cutting and have become essential to the implementation and understanding of the new capabilities afforded by nanotechnology and its insertion into Air Force Systems.

Research Topic Chiefs: LtCol Todd D. Steiner, AFOSR, 703-696-7314, todd.steiner@afosr.af.mil and Dr. Robert Barker, AFOSR, (703) 696-8574, robert.barker@afosr.af.mil

FY05 MURI Topic #21
Submit white papers and proposals to the Air Force Office of Scientific Research

COMPUTATIONAL MODELING OF ADVERSARY ATTITUDES AND BEHAVIORS

Background: Future "effects-based" military operations may be designed to diminish local support for groups directing violent activities against the U.S. or its allies. The local legitimacy of such groups represents this adversary's center of gravity, but is a socio-cultural phenomenon poorly captured by existing models of adversarial intent used for planning, training, and modeling the effects of military operations. While the values, attitudes, and beliefs of a local population do affect the degree of local support for adversaries, the dynamics of interaction among local sub-cultures and its relationship to the emergent property of support for violent adversaries is poorly understood. As a result, effects-based operations cannot be constructed to efficiently manage adversaries that rely on local popular support.

Objective: This topic encourages development of dynamic models of local attitudes and beliefs that drive adaptive collective decision making in a realistic environment. Such models would address adversarial intent, as opposed to capability, and attempt to characterize patterns of emergent behaviors driven by reaction to culturally interpreted changes in the environment that may include multi-cultural elements.

Research Concentration Areas: This topic encourages collaboration between, for example, social, behavioral, economic, and political scientists with computational researchers in artificial intelligence, control theory, and adaptive systems. Example topics include: (1) Exploring the structure of cultural knowledge, beliefs, and social norms either broadly, in factor models, or more narrowly, within the framework of a computational cognitive architecture; (2) Reasoning and decision-making processes in cultural context, including reasoning with uncertain information; (3) Self-organization and adaptation of culturally defined entities or groups, including models of group competitive and cooperative interactions; (4) Game-theoretic modeling of interactive agents with imperfect and incomplete information regarding other agents; and (5) New approaches to automated reasoning about belief, knowledge, obligation, time, and preference.

Impact: Research in this area will enable the development of new technologies for predicting adversarial intent and behavior, leading to technologies for culturally based military training, planning military operations in cultural contexts, and the modeling and simulation of the transformation of adversary to non-combative neutral.

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FY05 MURI Topic #22
Submit white papers and proposals to the Air Force Office of Scientific Research

WATER-BASED PHOTOBIOLOGICAL PRODUCTION OF HYDROGEN FUEL

Background: Molecular hydrogen (H_2) is envisioned as the energy source for fuel cells that will provide the power needs of future society, including the operation of a superior military. At the present time, the national plan is to extract H_2 from limited resources of coal, oil or gas using processes that require an energy source, produce huge amounts of waste by-products and defile the environment. Electrolysis of water can also yield H_2, but it likewise requires another energy source—usually fossil fuel- or nuclear-driven generators—to produce the electricity. An alternative approach that is both attractive and novel has recently been demonstrated. It uses microbes (algae or cyanobacteria) to generate H_2 photosynthetically from water, rather than sugars (food) from water and carbon dioxide (CO_2), but this has not yet been fully explored or understood. Because the product of H_2 combustion (water) is the actual substrate for the light-driven generation of H_2, the process is cyclical and renewable. Thus, such an energy source is virtually unlimited, cheap, carbon-free, clean and not just compatible with, but supportive of life. This light-driven process uses the two photosystems (PSI and PSII) of ordinary plant photosynthesis plus a special H_2-generating hydrogenase enzyme not found in ordinary plants. In brief, electrons (as well as protons and oxygen [O_2]) are released from the water-splitting enzyme of PSII, energized by PSI, and connected by an electron carrier (ferredoxin) to hydrogenase, an enzyme that evolves H_2. Enzymatic H_2 evolution (proton reduction) occurs under anaerobic conditions with the introduction of light. However, in a typical aerobic environment, hydrogenase is not produced and the electrons from PSI are instead used for CO_2 fixation. Thus, photosynthetic microbes represent unique biological systems capable of utilizing light energy and water to produce O_2 and, depending on their needs, either molecular H_2 or sugar/food. Other H_2-generating organisms exist as potential model systems, but they utilize substrate molecules (organic hydrocarbons, for example) that are more complex and less abundant than water, and often produce unusable (waste) by-products—making them less attractive as model systems for biomimetic research directed at future military applications. Fundamental research is required to identify and characterize the genetics, biomolecular components, and pathways involved in mediating H_2 production; to understand and enhance their individual and integrated structure/function relationships; and to elucidate mechanisms for controlling rates of H_2 generation. Acquisition of such knowledge will enable the development of enhanced H_2-generating microbes, which will serve as a biomimetic model to create small <u>artificial</u> systems for generating H_2 on demand.

Objective: The objective is to acquire the fundamental scientific knowledge necessary to engineer microbes that use water and light to generate H_2 in an aerobic environment. The microbe should display the following properties: robustness, enhanced photosynthetic efficiency, an O_2-tolerant H_2-generating hydrogenase with vigorous activity, and the capability for external regulation of the balance between H_2 and food production. The design and engineering of microbes with such properties will be difficult to achieve without understanding the molecular and physiological relationships that exist between photosynthesis and H_2-generating hydrogenases and identifying inefficiencies that currently limit the photobiological production of H_2.

Research Concentration Areas: Areas of research concentration that are thought to be integral to achieving the goals of this project are as follows: (1) identification of physiological, metabolic and genetic factors limiting H_2 generation, (2) role of steady-state electron transport and proton gradient build-up across the thylakoid membrane in limiting H_2 generation, (3) understanding the partitioning of photosynthetic reductant between CO_2 fixation and H_2 production, (4) X-ray structure analyses of hydrogenases, (5) approaches for generating robust, O_2-tolerant hydrogenases, (6) elucidation of the pathways, genes, and signaling processes related to on/off regulation of H_2 production, and (7) discovery of novel, robust organisms with enhanced H_2-generation for comparative studies. This list is meant neither to be comprehensive nor to exclude other ideas and approaches for achieving project objectives. Proposals must show a viable teaming arrangement among various universities and scientists (ranging from molecular biologists, biochemists and biophysicists to chemists and bioinformaticians). For more details refer to AFOSR website (www.afosr.af.mil) for "Biohydrogen" workshop report of meeting held in Golden, CO. (22-23 April 03).

Impact: Eventual applications resulting from breakthroughs in this research would have enormous impact on all sectors of society, especially the military. The knowledge derived from this research will be used to develop biomimetic models for engineering small synthetic generators that produce molecular H_2 and O_2 from water and light. Such a capability would enable energy independence from fossil fuels and, as a consequence, reduce the need for military actions—saving lives, capital and resources. Portable H_2 generators would provide for a deployable and distributed energy supply characterized by a reduction in logistic footprints and signatures (water as the combustion product) and, thereby, a reduction in force vulnerability. Since water would replace fossil fuels as the feedstock, fossil fuel use, exposures and health-related effects would all decline. In contrast to the synthetic generator, engineered green microbes would be especially promising as energy suppliers for any future manned space missions. While H_2 from the microbes would power fuel cells in space, O_2 from the microbes and water from the fuel cell-mediated oxidation of H_2 would support human life. Conversely, the human waste products of CO_2 and water would feed the microbes as they in turn produce food for human consumption. Thus, in space, green microbes would provide virtually unlimited energy for both machines and men by recycling their waste products in a "closed" system driven by light.

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FY05 MURI Topic #23
Submit white papers and proposals to the Air Force Office of Scientific Research

WAVEFORM DIVERSITY FOR FULL SPECTRAL DOMINANCE

Background: To maintain a superior technological edge under complex operational scenarios calls for sophisticated techniques including effective waveform diversity as a key enabling technology for high-performance integrated C4I from diverse platforms. With the available electromagnetic (EM) spectrum becoming increasingly scarce, a critical Department of Defense requirement in this context is one of multi-band, multi-modal, multi-sensor operation with multi-function processing from distributed platforms. Spatially distributed system components must function cooperatively to minimize interference and mitigate hostile activity while maximizing the utility of collected information. Application needs include sensing, communications, countermeasures, and network-centric warfare. End-to-end integrated optimization for sensor, communication or intelligence-gathering, relies on the design in real-time of waveforms that exploit diversity in many dimensions: transmitted power, bandwidth, center frequency, pulse shape and spreading, polarization, space-time and symbol coding. The design of the waveform set should be based on the propagation/interference environment, which is determined through probing and/or feedback, calibrated to realistic models of the Radio Frequency (RF), multi-user, and network environment or each transceiver. As certain aspects of this information naturally evolve with time, waveform generation resources must optimally and adaptively be integrated with electromagnetic phenomenology. This and other available knowledge is gathered through physical, experimental, and data-dependent approaches. Finally, waveform diversity systems must incorporate robustness to “model mismatch” as well as to parameter estimation error.

Objective: To advance the multidisciplinary fundamental aspects of waveform-diversity sensors and systems for enhanced performance in fiercely contentious operational scenarios, by making efficient use of all available “transmit and receive” resources.

Research Concentration Areas: Areas of interest include but are not limited to:
Design of multi-dimensional waveform sets exploiting diversity for multi-path gains and interference avoidance through synergistic transmission and receiver processing; Re-configurable transmission techniques and receiver algorithms; Multiple-input/Multiple-output (MIMO) systems for sensing and communications; Software/Cognitive Radio; Flexible multiple access schemes; Channel characterization and prediction; Interference suppression methods; Adaptive modulation, coding, encryption and decryption; Networked sensor operation; Cross-layer optimization; Stochastic optimization for end-to-end system configuration; Dynamic information exploitation; Environmental and target attribute modeling.

Impact: Successful research in this area will produce a suite of approaches validated by extensive analysis for improved system performance, thus fostering integrated C4I operation from diverse platforms. Research in this area will support the development of systems capable of dynamically adapting waveforms, processing, and information extraction to changing operational scenarios. Parameterized waveform families will facilitate these capabilities, along with configurable signal processing algorithms, under the control of stochastic optimization algorithms.

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FY05 MURI Topic #24
Submit white papers and proposals to the Air Force Office of Scientific Research

CLOSED-LOOP AERODYNAMIC FLOW CONTROL

Background: Recent advances in sensor and actuator technologies, computational capability, order reduction techniques and the control sciences have enabled a fundamentally new perspective on the manipulation of fluid flow over lifting surfaces using active control methods. Current approaches to the active control of fluid flows can be open-loop or closed-loop, but application of closed-loop (feedback) control to flow problems has the potential for enhanced performance over open-loop approaches. Feedback flow control can also provide flexibility in design and robustness to perturbations, as well as adaptability to a larger operating envelope. However, these advantages come at a major computational cost: the dimension of a typical discretization of the fluid model by Computational Fluid Dynamics (CFD) methods is generally too large for a computationally tractable feedback implementation. The real-time implementation of feedback control techniques on flow problems requires a reduction in the complexity of the fluid model described by the Navier-Stokes equations. Hence, research efforts have focused on reduced-order modeling for control design as well as for flow simulations. In addition to incorporating feedback, control theory has opened up new areas of research in fluid mechanics, including control architecture optimization and characterization of fundamental system limitations. Optimization of the control architecture occurs in problems such as finding the optimal placement of sensors and actuators, while understanding fundamental limitations of achievable performance based on computational and theoretical studies helps in choosing the proper actuation device before construction of the necessary hardware begins. Given the complexity of issues encountered in flow control problems, there is need for more cohesive work in all of the above areas. A merging of computationally tractable and accurate simulation, feedback control, optimization, characterization of controlled fluid systems and experimental validation is necessary to provide new insights into the control of unsteady flows.

Objective: Develop a theoretical, computational and experimental tool set to allow optimization of closed-loop flow control systems for aerospace vehicles incorporating unsteady flow forcing and enabling 1) enhanced endurance, 2) flight control without conventional wing and tail control surfaces, 3) enhanced maneuverability, 4) robustness to disturbances, and Mach number and Reynolds number variations, 5) control re-allocation to provide damage tolerance, 6) hierarchical control approaches for nonlinear interactions of distributed actuators, 7) experimental validation of the actuation concept and control architecture, and 8) system level analysis to provide objective/cost functions for incorporating closed-loop flow control weight and power penalties into vehicle design methodologies. The robust feedback control architecture should be capable of optimizing closed-loop periodic forcing inputs for application over entire flight envelopes.

Research concentration areas: The multidisciplinary research team should include expertise in computational fluid mechanics, model order reduction, optimization, dynamical systems, control theory, sensors, actuators, and experimental methods. Multidisciplinary elements are expected to include: time-accurate computational fluid dynamics simulations, including fluid-actuator interactions; reduced-order models for both uncontrolled and controlled flows, including the dynamics of the fluid response to changes in actuator parameters; a comprehensive model-based feedback flow control structure where optimization of the architecture is integrated into the closed-loop problem definition; experimental validation of realizable feedback flow control systems designed using CFD simulation tools and order reduction; integration efforts addressing system level issues associated with implementation of these control concepts; robust and adaptive control of distributed parameter systems to address parameter variations, sensor noise and model uncertainty; and characterization of fundamental limitations on performance.

Impact: The management of aerodynamic forces and moments on a maneuvering vehicle through closed-loop flow control will allow high performance manned and unmanned air vehicles to operate with reduced drag, increased fuel efficiency, and increased control authority. Furthermore, implementing closed-loop feedback flow control on new systems such as micro-air vehicles will contribute to the capability for unconventional operations.

Research Topic Chiefs: Dr. Fariba Fahroo, AFOSR, 703-696-8429, fariba.fahroo@afosr.af.mil
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FY05 MURI Topic #25
Submit white papers and proposals to the Air Force Office of Scientific Research

MULTISTAGE ELECTROMAGNETIC (EM) AND LASER LAUNCHERS FOR AFFORDABLE, RAPID ACCESS TO SPACE

Background: There is significant need to investigate the science and technology required to enable affordable, rapid access to space for today's new classes of viable sub-kilogram payloads. This research opportunity is the key for space support transformational capability, in order to provide quick-turn, On-Demand, assured Space Access for time-sensitive military operations. The inherent low efficiency of rocket systems (one must boost the propulsion system with the payload) entails a cost of more than $20,000 per kg into orbit. With increasing DoD interest in launching robust "micro-" payloads in the range of 0.4-10 kg. into earth orbit, the stage has been set for a revolutionary reduction in the mission cost through the use of ground- or air-based payload launchers. Both multistage electromagnetic launchers and laser-propelled trans-atmospheric vehicle concepts offer the potential for orders-of-magnitude reductions in launch cost to below $600/kg and also a rapid-launch-on-demand capability that will revolutionize thinking in this field. Army programs over the past decade have evolved electro-mechanical systems mounted in artillery shells that can tolerate tens of thousands of g's of acceleration. It is this combination of microsatellite technology combined with high-g tolerant electronics that makes the launch cost breakthrough possible if the appropriate electromagnetic launcher concept can be created. In order to eliminate the problem of rail erosion in electromagnetic launchers, it is desirable to concentrate on *multistage* launcher concepts that would steadily feed increasing amounts of kinetic energy to the projectile over a long acceleration track. This will lower g-force stress on the payload while also spreading out the electrical and thermal loads on the launcher. Unfortunately, there are no existing multistage launcher systems under study today. The Army's large programs in this arena have concentrated on compact single-stage launchers for ease of employment on mobile land vehicles. At the same time, Air Force programs have concentrated on a laser-supported lightcraft concept that was a microsatellite in which the laser propulsion engine and satellite hardware were intimately shared. The forebody aeroshell acted as an external compression surface. The afterbody had a dual function as a primary receptive optic (parabolic mirror) for the laser beam and as an external expansion surface (plug nozzle) during the laser rocket mode, which is used only in space. This research program must now take those concepts into entirely new regimes. Luckily, there exist a fair number of multi-megajoule university facilities that could be retooled to host appropriate experiments along these lines.

Objective: The objectives are to investigate the innovation of a high efficiency multi-stage railgun and/or coilgun that feeds energy to a subkilogram payload as it is accelerated through the barrel and to study the basic research issues associated with the high heat loads of such systems including research in materials, coatings, and structures; and to advance laser- propelled trans-atmospheric vehicle concept through theoretical and experimental studies. Exploring the gee limits for payloads of AF interest will be an important aspect of this effort that might be borrowed from current AF MicroSatellite programs.

Research Concentration Areas: Suggested research areas are as follows: (1) investigate high-current energy-injection, and advanced electromagnetic acceleration concepts; (2) focus on multistage launcher concepts and possibly include some magnetic levitation features. (3) study payload/projectile shape in relation to thermal aerodynamic heating problem through aerodynamic analysis and computational modeling. (4) develop novel means for passive and active control of aerodynamic heating under high-g condition, such as evaporative boundary layer cooling techniques including reciprocating heat loop or ablative shields including new high temperature materials and functionally graded materials. (5) develop high-speed electronic diagnostics on board the test projectiles in the experimental gun; and (6) create and validate robust computational methods that can model the time dependent dynamic, electrical, and thermal processes in such systems. (7) model and control atmospheric beam propagation and laser-supported detonation waves. (8) optimize lightcraft satellite/payload shape and (9) investigate combined laser propulsion cycles from airbreathing to rocket as a function of attitude.

Impact: This research is expected to provide fundamentals that can lead to the next generation spacelift concepts that can significantly reduce time and cost of space operations.

Research Topic Chiefs: Dr. Mitat A. Birkan, AFOSR, 703-696-7234, mitat.birkan@afosr.af.mil
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FY05 MURI Topic #26
Submit white papers and proposals to the Air Force Office of Scientific Research

BIOMIMETIC MULTIFUNCTIONAL COMPOSITES FOR "AUTONOMIC" AEROSPACE STRUCTURES

Background: Biological systems are inherently hierarchical, multifunctional and autonomic. For example, a muscle consists of muscle fibers each of which then is a collection of myofibrils. Each myofibril contains myosin and actin filaments for the contractile mechanism. A bone, which is ceramic composites with functional gradients, serves as a load-bearing frame with self-lubricating joints. A human skin consists of collagen fibers in a porous polysaccharide matrix containing circulatory networks for sensing and perspiration. For a chameleon, the skin even changes its color in response to external stimuli. In the past decades, progress has been made to develop synthetic composites that can mimic the compositions of biological systems. Examples are artificial skins for burn patients and artificial bones for implant.

The next logical step is to develop synthetic composites that can mimic some of the *multi-functions* of biological systems. These multifunctional composites can be incorporated into load-bearing aerospace structures (e.g. sensorcraft, space mirror) as a skin or a structural frame thereby providing a variety of advanced capability. In fact, with recent research progress, it is possible to utilize micro- or nano-scale *smart materials* to design and synthesize biomimetic composites with optimum morphologies guided by biological systems. Also, a number of *micro- or nano-morphologies* are conceivable with different types of smart materials: porous membranes, rods, platelets, cages, tubes, coils, solid fibrils, hollow filaments, etc. By choosing proper materials with correct morphologies one can incorporate the desired biomimetic performance into composite structures. Potential benefits of such biomimetic composites include autonomic response of *self-diagnosis*, *self-healing*, *threat neutralization*, etc.. Biomimetic composites may even perform *self-cooling* operation through *pulsed* fluid transport or reservoir in micro- or nano-scale. All of these ideas can be aided by scientific progress achieved in micro- or nano-devices as well.

However, a number of questions on design, synthesis, processing, and performance remain to be answered before these biomimetic composites can be realized for autonomic response. How can we define biological features of autonomic function of human body, specifically self-diagnosis, self-healing, self-cooling and threat neutralization capabilities, in terms of molecular engineering and materials architecture? What would be the optimum morphologies of composites for different functions? What would be the length scales where the benefits of smallness begin to be realized? How to tailor and produce the desired micro- or nano-morphologies of smart materials? An analytical framework should be formulated to achieve a fully integrated design procedure for true biomimetic performance of coupled multifunctionality (instead of a mere collection of different functional properties). The topic will require an *integration of science and engineering* to develop biomimetic composites for autonomic response with adequate load-bearing capability. Such biomimetic composites will enable advanced capability in future military systems and aerospace structures.

Objective: (a) To understand biological nature of autonomic function of human body, specifically self-diagnosis, self-healing, self-cooling and threat neutralization capabilities; (b) to synthesize, process, and characterize biomimetic composites which incorporate smart materials with optimum micro- or nano-morphologies; and (c) to develop a scientific foundation for the design and manufacture of biomimetic composites offering autonomic response of self-diagnosis, self-healing, self-cooling and threat neutralization along with adequate load-bearing capability.

Research Concentration Areas: Suggested research areas are as follows. (1) theoretical and experimental understanding of the structure and autonomic response of appropriate biological systems; (2) synthesis and processing of smart materials and devices with optimum micro- or nano-morphologies: (3) processing and surface sciences for the control of morphology, distribution and stability of micro- or nano-phase materials at various structural levels; (4) manufacturing and characterization of biomimetic composites offering multifunctional capabilities and autonomic response, such as self-diagnosis, self-healing, self-cooling and threat neutralization, along with adequate load-bearing capability; (5) validated modeling and simulation of biomimetic performance of coupled multifunctionality to achieve a fully integrated design procedure. The proposal should clearly indicate application areas and show how the expected research results can be transitioned to those application areas.

Impact: This research is expected to significantly reduce weight, size, and life cycle costs of military systems while lengthening their lifetime and improving their performance. It will open the door for a whole new generation of biomimetic composites capable of autonomic response with their load-bearing capability intact or further improved. A fully optimized biomimetic multifunctional structure will be able to detect and mitigate internal damage as well as heat build-up in advanced military systems such as hypersonic airplanes and space vehicles. These new material systems will necessitate a completely new design paradigm where multidisciplinary approaches are required to handle biomimetic performance.

Research Topic Chiefs: Dr. B. "Les" Lee, AFOSR, 703-696-8483, Les.Lee@afosr.af.mil
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IX. COVER

Submitted in response to FY 2005 DoD Multidisciplinary Research Program of the University Research Initiative BAA

TECHNICAL PROPOSAL COVER
(This form must be completed and submitted as the cover of the proposal)

BAA NUMBER: 04-________

1. THE PRINCIPAL INVESTIGATOR (One name only)

____ ____________________________________
(Title) (First Name) (MI) (Last Name) PI Signature (please use blue ink)

(______)___________________ (_______)_______________ ___________________________
(Phone Number) (FAX Number) (E-mail address)

____
(Institution/Department/Division)

____
(Street/PO Box/Building)

____
(City) (State) (Zip Code)

Other universities involved in the MURI team if any____

____

CURRENT DoD CONTRACTOR OR GRANTEE: YES_____NO_____

If yes, give Agency, Point of Contact, Phone Number:____

____

2. THE PROPOSAL:

____
(Title; be brief and descriptive; do not use acronyms or mathematical or scientific notation)

1 MAY 2005 to 30 APR 2008 1 MAY 2008 to 30 APR 2010 ______________________________
Proposed Base Period Proposed Option Period Your Institution's Proposal Number

Submitted to: ____
DOD Agency/ Topic #/ Topic Title

Total funds requested from DOD:
______________ + _________________ = _____________________
3-year base total 2-year option total 5-year total

OTHER AGENCIES RECEIVING THIS RESEARCH FUNDING REQUEST
(e.g., NSF, DOE, NASA, NIH). Please identify agency(ies) and give Name(s) and Phone Number(s) of Point(s) of Contact at those agencies:

____

3. MINORITY INSTITUTION: _____ Check here if the academic institution named above is qualified to be identified by the Department of Education as a minority institution (i.e., a historically Black college or university, Hispanic-serving institution, Tribal college or university, or other institution meeting statutorily-defined criteria for serving ethnic groups that are underrepresented in science and engineering). The Department of Education maintains the list of U.S. accredited postsecondary institutions that currently meet the statutory criteria for identification as minority institutions at the following web site: http://www.ed.gov/offices/OCR/minorityinst.html

4. THE INSTITUTION: NAME AND ADDRESS OF UNIVERSITY OFFICIAL AUTHORIZED TO OBLIGATE CONTRACTUALLY AND WITH WHOM BUSINESS NEGOTIATIONS SHOULD BE CONDUCTED:

____
(Title) (First Name) (MI) (Last Name)

(______)_______________ (_______)_________________ __________________________
(Phone Number) (Fax Number) (E-mail address)

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Name of Grantee (University)

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Street Address (P.O. Box Numbers Cannot Be Accepted)

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(City) (State) (Zip Code)

Taxpayer Identification No. (TIN)[1]_______________________DUNS No.[2]____________________

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Signature of Authorized University Official Date
(Please use blue ink)

[1] The DoD is required by 31 U.S.C. 7701 to obtain each recipient's TIN (usually the Employer Identification Number) for purposes of collecting and reporting on any delinquent amounts that may arise out of the recipient's relationship with the Government.

[2] The institution's number in the data universal numbering system (DUNS) is a unique nine digit (all numeric) identification number for organizations. Dun & Bradstreet Corporation assigns it. You can receive a DUNS number by calling Dun & Bradstreet at 1(800) 333-0505 or go to the Dun & Bradstreet Web site at http://www.dnb.com/dnbhome.htm.

X. ACKNOWLEDGMENT FORM

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Date:

Dear Proposer:

Your FY2005 Multidisciplinary URI research proposal has been received at:

ARO ____ ONR _____ AFOSR _____

____and will be evaluated, Control Number______________

____will not be evaluated for the following reason(s):

Letters announcing award recommendations will be mailed by about late-February 2005.