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THE DEPARTMENT OF DEFENSE UNIVERSITY RESEARCH INITIATIVE RESEARCH PROGRAM SUMMARIES

JUNE 1987

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PARTICIPATING ORGANIZATIONS:

Department of the Army

Department of the Navy

Department of the Air Force

Defense Advanced Research Projects Agency
in cooperation with the Office of the
Under Secretary of Defense for Acquisition

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UNIVERSITY RESEARCH INITIATIVE
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The Department of Defense
University Research Initiative
Research Program Summaries

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I. PURPOSE

→ This compilation of University Research Initiative (URI) program summaries has been prepared in response to numerous requests for information about the URI, the newest basic research program of the Department of Defense (DoD). This document directly addresses the most frequently asked, general questions about URI research programs and provides points of contact where more specific information about each program may be sought.

It is hoped that this document will stimulate further interest among university researchers, who may be inspired to participate in DoD basic research programs in the future; among researchers in federal laboratories or in industry, who may be encouraged to initiate mutually beneficial collaborations with the programs described herein; and among defense and research policymakers, who may wish to track the progress of the innovative URI program. DoD is proud of the URI and is pleased to make this information available for all of these purposes.

↑

II. INTRODUCTION

In the United States, university research pays double dividends, producing both new knowledge and new talent. The Department of Defense values these dual benefits because national defense strategy relies upon maintaining a competitive edge in science and technology. Sustaining a competitive advantage requires a substantial investment in human resources, the future scientists and engineers that universities train, as well as in efforts to produce new scientific and engineering knowledge.

The University Research Initiative strengthens the Department's commitment to the university research community. It is designed to enhance the capabilities of universities to perform research and to educate scientists and engineers in disciplines that underpin technologies important to national defense.

The URI was initiated in 1986. Congress provided \$90 million for the URI in FY 1986 (after Gramm-Rudman-Hollings and other reductions) and \$35 million in FY 1987. The Services and DARPA conducted open competitions, and more than 170 academic institutions submitted a total of nearly 1,000 proposals, requesting more than \$1 billion per year in research funding. Eighty-six research programs were selected in merit-based, technical competitions. FY 1986 and 1987 funds were combined to fund the initial period of research effort, from the time the final funding documents were negotiated and signed late in FY 1986 through the end of FY 1987.

Approximately 85% of the URI funds are allocated to these multidisciplinary research programs. The remaining funds support "people programs," which include graduate fellowships, young investigator awards, and scientific personnel exchanges.

URI: Multidisciplinary Research. The multidisciplinary research programs, described in Chapter III of this report, generally are envisioned as 3-5 year efforts, with review and evaluation after 3 years. Funding for each program generally includes the cost of research instrumentation and support for graduate students, as well as operating expenses for the research effort.

The multidisciplinary framework of the URI has multiple advantages. With scientists and engineers working side by side, multidisciplinary research helps to bridge the transition between basic and applied research. The process by which new scientific discoveries are translated to practical technological applications is therefore hastened. These applications will doubtless include commercial spinoffs as well as advanced defense systems.

By serving as sources for technology diffusion, University Research Initiative programs should promote commercial applications of defense research. The URI strongly encourages universities to collaborate in their multidisciplinary programs with science and engineering personnel

from DoD laboratories. Industrial participation also will occur in many cases, creating fertile ground for collaboration and technology sharing among government, universities, and industry.

JRI multidisciplinary programs are focused on technologies that are critical to national defense but, as implied above, many of these tend to be dual-use technologies with good potential for commercial applications as well. For example, DoD has initiated URI programs in technologies for automation, including robotics, artificial intelligence, computers, and manufacturing science. Other areas of research effort include biotechnology, high-performance materials, lasers and electro-optical devices, high-frequency microelectronics, and advanced propulsion systems. All of these defense research areas have excellent potential for generating new commercial products and processes to help U.S. industrial productivity and competitiveness.

URI: Science and Engineering Education. The URI provides exceptional educational opportunities in the science and engineering fields that contribute to each of the multidisciplinary URI programs. Graduate students participate in team research addressing specific technological problems. They also have access to state-of-the-art research equipment that URI instrumentation funds make available. The URI experience should be of great long-term value to students and to their future employers.

To further promote science and engineering education, some URI funds are being used separately to fund graduate student fellowships, young faculty investigator awards, scientific exchanges, and several Navy chairs in oceanography. By encouraging U.S. citizens to pursue advanced study in science and engineering, URI graduate fellowships address the problem of the falling fraction of U.S. students relative to foreign students in many fields of greatest interest to DoD. Research awards for young faculty investigators should help alleviate problems with recruitment and retention of new faculty.

Of course, the University Research Initiative is only the latest avenue for university participation in DoD's basic research program. Universities also perform more than half of the research funded under Defense Research Sciences (DRS), DoD's core basic research program. The multidisciplinary programs of the new URI are complementary to DRS inasmuch as DRS has traditionally emphasized awards for single investigators. Further information about DoD's university research programs, both DRS and the URI, may be obtained by contacting the research offices in the Services and Defense Agencies:

ARMY

Director
U.S. Army Research Office
ATTN: SLCRO-ZC
Research Triangle Park
NC 27709-2211
919-549-0641

ARMY (Cont'd)

Research and Development Office
Office of the Chief of Engineers
ATTN: DAEN-RDZ-A
20th Street and Massachusetts Avenue, N.W.,
Room 6208
Washington, DC 20314-1000
202-272-0254

Assistant Surgeon General for Research and Development
Office of the Surgeon General
ATTN: DASG-RDZ
The Pentagon, Room 3E474
Washington, DC 20310-2300

Technical Director
U.S. Army Research Institute for the Behavioral & Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333-5600
202-274-8636

NAVY

Director
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5000
202-696-4517

AIR FORCE

Commander
U.S. Air Force Office of Scientific Research
Bolling AFB
Washington, DC 20332-6448
202-767-5017

DARPA

Deputy Director for Research
Defense Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209-2308
202-694-3035

III. SUMMARIES OF MULTIDISCIPLINARY RESEARCH PROGRAMS

The following are brief synopses of each of the 86 URI multidisciplinary research programs selected for funding in the 1986 merit competition. The program descriptions are grouped into Sections A through J, according to the ten broad research areas that were selected for competition. Also indicated are the specific areas emphasized by each funding agency within the ten broad research categories.

Each program summary lists a short title for the program and the name, address, and telephone number for the principal investigator and his or her institution. Some programs involve consortia of academic institutions, and the additional participants are shown for those programs.

The name and telephone number of the cognizant DoD scientific officer or program manager is given for each URI effort. The sponsoring Service is indicated by the acronym ARO (Army Research Office), ONR (Office of Naval Research), AFOSR (Air Force Office of Scientific Research), or DARPA (Defense Advanced Research Projects Agency). Addresses for these organizations are given in the preceding section of this report.

A. MATHEMATICAL ANALYSIS, MODELING, AND SIMULATION

Services' Areas of Emphasis:

Mathematics (ONR)

Research in Mathematical Analysis, Modeling and
Simulation (AFOSR)

TITLE

Combinatorics in C3

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. William R. Verry

(804) 656-3434

Clemson University
Department of Mathematical Sciences
Clemson, SC 29634

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Fred R. McMorris (202) 696-4362

SERVICE

ONR

ABSTRACT

The Clemson University Research Initiative Program in the Department of Mathematical Sciences will investigate basic and applied problems in discrete mathematics and computational analysis. Clemson University has augmented the award by providing one half the cost of a Floating Point Systems sixteen node T-20 hypercube computer and the establishment of an advanced computing facility.

Three research tasks by five Principal Investigators are sponsored in the area of discrete mathematics. Professor C.R. Johnson's Applied Combinatorial Matrix Analysis uses combinatorial ideas in the study of matrix analysis problems. In Combinatorial Structures and Network Reliability Professors D.R. Shier and J.P. Jarvis are conducting an extensive investigation of the rich combinatorial structure that underlies network reliability problems and the development of more efficient algorithms for assessing network reliability. Professors S.T. Hedetniemi and R.C. Laskar are involved in Development of Linear Algorithms on Combinatorial Structures which continues to effectively characterize combinatorial problems for which there are linear time solution algorithms.

The area of computational analysis also has three projects directed by seven Principal Investigators. Professor D.D. Warner joins C.R. Johnson to investigate Hierarchical Systems where they are extending the results of prior work concerning analytic properties of hierarchical matrices and developing mathematical algorithms for data analysis on parallel computing architectures. In Distributed Control of a Multimodal System Professors R.E. Fennell, R.E. Haymond and J.A. Reneke are developing control coordination methods based on simulation of realistic examples for multimodal systems. Professors J.R. Brannan and T.G. Proctor in Parameter Estimation and Control in Nonlinear Dynamical Systems are developing a methodology for estimating initial conditions or coefficients in partial differential equations based on treating the system states as measurement functionals of the unknowns.

The Clemson Advanced Computing Facility includes a Floating Point System T-20 hypercube computer. The FPS T-20 is one of the first "supercomputer-class machines based on massive parallelism." The availability of this machine provides a unique opportunity to develop computational capabilities for parallel computers. The T-20 is in addition to the usual University computing capabilities: a NAS AS/XL60 Dual Processor, a DEC VAX 8650, a DEC VAX 8600, and a DEC VAX 11/780. The FPS T-20 uses a hypercube architecture with 16 vector processing nodes. The architecture provides two levels of concurrency, parallelism between nodes and pipelining within each node. The Clemson T-20 configuration has a peak performance greater than a CRAY 1.

TITLE

Center for Analysis of Heterogeneous and Nonlinear Media

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Russell Caflisch

(212) 460-7362

New York University
Department of Mathematical Sciences
New York, NY 10012

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Arje Nachman (202) 767-5027

SERVICE

AFOSR

ABSTRACT

A center is being established at the Courant Institute to perform research on the behavior of heterogeneous and nonlinear media. The main research areas are: nonlinear optical media, dynamics of fluid interfaces, and composite and random media. The main goals are the development of new analytic methods, formulation of theoretical models of physical phenomena and applications to specific problems. Important features of the Center will be close interplay between numerical computation and mathematical analysis, and training of graduate students and postdoctoral researchers.

TITLE

Computational Combinatorics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Thomas L. Morin

(317) 494-5418

Purdue University
Purdue Research Foundation
Hovde Hall, 3rd Floor
West Lafayette, IN 47907

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Neal D. Glassman

(202) 696-4313

SERVICE

ONR

ABSTRACT

Combinatorics is one of the fastest growing areas in all of mathematics. It has traditionally been concerned with questions involving the existence and enumeration of discrete objects related in ways typically other than the binary operations of classical algebra. More recently, attention has focused on the computational aspects of combinatorics, i.e., on optimization and on the design and analysis of computer-based algorithms for various combinatorial structures. Indeed, the computational phases are emerging as a new mainstream of applied mathematics, paralleling traditional branches which address continuous and dynamic phenomena.

This research initiative will initially focus on several key areas in computational combinatorics that are also critical DoD objectives. These include: algorithmic graph theory, computational geometry, matroid theory, polyhedral methods, foundations of heuristics, and computational dynamic programming.

The array of vital military and civilian technologies supported by computational combinatorics is an immensely diverse one. Automated batch manufacturing and robotics have posed a variety of new discrete decision models addressed to the control of industrial-type systems. Military logistics and force planning are among the earliest and most persistent concepts of this field. Computer aids for battle management and virtually all controllers for modern combat systems have combinatorial decision models set their course. Management and security of military communications depends directly on combinatorial control and the combinatorics of cryptology.

TITLE

Transition to Complicated Behavior in Infinite Dimensional Dynamical Systems

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Alan C. Newell

(602) 621-6893

University of Arizona
Department of Mathematics
Tucson, AZ 85721

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Arje Nachman (202) 767-5027

SERVICE

AFOSR

ABSTRACT

The primary goals of our work are to develop ways of thinking about, understanding and utilizing at a practical level the complicated behavior exhibited by deterministic dynamical systems. We are particularly interested in the problems of fluid and optical turbulence. For the immediate future, our aim is to determine to what extent the revolutionary ideas of the last decade can be applied to infinite dimensional systems (partial differential equations), to explore the routes by which such systems develop broadband power spectra and in particular to understand the onset of complicated spatial behavior. The ultimate hope, of course, is to develop models which will accurately predict the transport of heat, mass and momentum as a function of the externally applied fields. In the optical context, our hope is to develop theoretical models which will help in the development of practical and useful optical devices (switches for optical computers, nonlinear waveguide devices, information transmission in nonlinear optical fibers).

TITLE

Research in Computation and Applied Mathematics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Paul Roberts

(213) 206-2707

University of California at Los Angeles
Departments of Mathematics and Geophysics
Los Angeles, CA 90024

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Richard L. Lau

(202) 696-4316

SERVICE

ONR

ABSTRACT

The UCLA group in applied and combinatorial mathematics will develop numerical and analytical techniques that will be useful in solving problems arising in continuum mechanics, and particularly fluid mechanics. As test-beds for these techniques, they have selected a number of specific areas in which they have special competence. Some of these areas test principally the numerical methods, others the analytic methods, and yet a third class requires a dual attack using both analytic and numerical weapons.

The focus is on the challenging problems that arise when solutions are neither smooth nor well behaved. The phenomena to be studied are steep gradients in the solutions and their limiting cases with interfaces. Typical steep gradient problems are boundary layers, turning points, viscous shock profiles and domains with oscillation e.g. turbulence. Interface problems involve shocks and problems with fixed or moving physical and computational boundaries.

The problems discussed here are difficult but interesting for numerical methods. In order to resolve a solution which changes drastically over a small distance, a dense computational grid can be used. This often carries an excessively high computational cost. Special techniques have to be developed that produce a good approximate solution or a realistically dense grid. Shock capturing and vortex methods are examples of such techniques. It is the purpose of the proposed work to improve such methods and to extend the theory with necessary and sufficient conditions for numerical convergence.

Problem areas that are ripe for a combined analytic/numerical attack form an unusual aspect of this project. The project addresses the general question of the stability of multi dimensional solitary wave solutions of some of the classic equations of applied mathematics: the nonlinear Schrodinger equation, the Kadomtsev-Petviashvili equation, etc. When such a wave is disturbed it will, typically, radiate energy and momentum to infinity before settling down

to a new solitary wave form (stability) or evanescent (instability). It is necessary to devise numerical techniques that filter out all but the out-going radiation. For many physical problems with boundary layer regions it is most efficient to develop an analytic understanding of the structure of these regions and to incorporate this understanding into a viable numerical scheme of solution. The group will study several problems of this type (i) evolution of a mushy zone in a freezing material, (ii) development of narrow reaction zones in non-linear diffusion problems, and (iii) buckling of thin elastic structures with small holes.

B. TECHNOLOGIES FOR AUTOMATION: ROBOTICS, AI, COMPUTERS, MANUFACTURING SCIENCE

Services' Areas of Emphasis:

Intelligent Control Systems (ARO)

Manufacturing Science, Reliability and Maintainability
Enhancement (ARO)

Robotics (ONR)

Artificial Intelligence (ONR)

Computer Science (ONR)

Manufacturing Science and Production Engineering (ONR)

Research on Enhanced Computing Environments (AFOSR)

Distributed Parameter Control (AFOSR)

TITLE

Control of Distributed Parameter Systems

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. H. T. Banks

(401) 863-3248

Brown University
Division of Applied Mathematics
Providence, RI 02912

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Marc Q. Jacobs

(202) 767-4939

SERVICE

AFOSR

ABSTRACT

A Center of Excellence at Brown University is being instituted to perform research in an interdisciplinary, integrated effort emphasizing the experimental, theoretical, and computational aspects of control of Distributed Parameter Systems. The topics of investigation proposed include the development of new and advanced distributed models including damping for large flexible structures, the development of system identification and feedback control methodology for such models, the development of computational algorithms for use with state-of-the-art vector and parallel computer architectures, and a program of experimental testing and verification for the models and control and estimation techniques developed.

TITLE

Learning and Discovery

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Allen Newell

(412) 268-2602

Carnegie Mellon University
Computer Science Department
Pittsburgh, PA 15213

ADDITIONAL PARTICIPATING INSTITUTIONS

University of Pittsburgh

SCIENTIFIC OFFICER

Dr. Alan L. Meyrowitz (202) 696-4302

SERVICE

ONR

ABSTRACT

The research program spans three organizations: the CMU Computer Science department, the CMU Psychology Department, and the Learning Research and Development Center at the University of Pittsburgh. Collaboration is being encouraged among participating scientists in order to increase the translation of ideas from the study of human intelligence into AI systems and technology. An interdisciplinary graduate program is being instituted that trains students in AI and cognitive psychology. Initially, the program will undertake projects in three research areas:

Learning Systems. Each project is building an expert problem solver that learns. The projects vary in the representations they use for acquired knowledge, and in the balance they strike between learning from experience (adaptive problem solving) and learning from instruction. The projects and their leaders are:

- o Models of skill acquisition and their application to intelligent tutoring systems (John Anderson),
- o Autonomous learning systems (Jaime Carbonell),
- o Learning algorithms for parallel processing mechanisms (Jay McClelland, Geoff Hinton, David Touretzky),
- o Models of human cognition (Allen Newell),
- o A hybrid symbolic/connectionist architecture (Walter Schneider),
- o A design space for learning systems (Kurt VanLehn).

Discovery systems. These projects are aimed at long-range results that contribute to the understanding of how discoveries are made. The emphasis is on the processes involved in generating hypothesis and designing experiments to test them. The primary project will be:

- o Learning mechanisms in scientific discovery (Herbert Simon).

Tutoring systems. These projects are aimed at near-term results. They

will produce tutors for training specific subject matter areas. These projects will push theories of learning forward by grounding them in the learning performance of real human students. The primary project is:

- o Intelligent interfaces that teach (Jeffrey Bonar, Alan Lesgold).

TITLE

Center for Intelligent Control Systems

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Sanjoy K. Mitter

(617) 253-2160

Massachusetts Institute of Technology
Department of Electrical Engineering
Cambridge, MA 02139

ADDITIONAL PARTICIPATING INSTITUTIONS

Brown University, Harvard University

SCIENTIFIC OFFICER

Dr. Gerald R. Andersen

(919) 549-0641

SERVICE

ARO

ABSTRACT

The Center for the Study of Intelligent Control Systems will be operated by a consortium consisting of Brown University, Harvard University, and Massachusetts Institute of Technology, with the headquarters at MIT. The research and educational mission of this Center will be directed toward the further development of the conceptual and mathematical aspects of this subject, drawing on relevant work in mathematical and computer sciences, including work in system and control theory and communication theory. Recent developments in microelectronics, computer and communication technology have made it possible to develop sophisticated guidance and control and Command, Communication and Control systems in hardware form. However, exploiting the full capabilities of such systems requires commensurate development in theory, algorithms and robust software. The proposed Center will provide such a forum for research on intelligent control systems. An important aspect of the Center will be its role as a meeting ground for researchers both inside and outside academia. Because of the broad range of technologies and applications areas which need to be coupled with the analytical work, an environment will be created that encourages students and researchers to develop broad contacts. The Center will serve as a resource for the Army as well as a national center for fundamental research in intelligent control systems. The potential contributions of this Center to the Army include:

- o Development of algorithms and prototype software for intelligent control systems
- o New computational architecture for parallel and distributed computation with further possible prototype development, and
- o Advanced education of Army scientists and engineers in the relevant areas.

TITLE

Research on Robotics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Patrick H. Winston

(617) 253-6754

Massachusetts Institute of Technology
Artificial Intelligence Laboratory
545 Technology Square
Cambridge, MA 02139

ADDITIONAL PARTICIPATING INSTITUTIONS

University of Utah

SCIENTIFIC OFFICER

Dr. Alan L. Meyrowitz (202) 696-4302

SERVICE

ONR

ABSTRACT

Most existing work on robotics is oriented toward factory applications and therefore rests on the assumption that tasks are performed in carefully prepared, structured environments.

Removing the structured-environment is the intent of the MIT research; it forces more ambitious, more fundamental research on individual robot competences like motion planning and three-dimensional vision. The variability in an unstructured environment is bad enough without faulty sensing and inaccurate object models, so the research will seek better sensing and model-building theories. But beyond improvements in these individual abilities, real-world variability calls for competence integration. Because industrial environments are assumed relatively fixed, most current robotics research can afford to concentrate on isolated, narrowly-defined competences such as position control, force control, edge finding, stereo vision, path planning, and navigation. The robot must be able to adapt on its own, juggling and integrating a wide number of perceptual, reasoning, and action abilities in order to grapple with the wider range of possibilities in an unstructured environment.

Because the connection between perception and action cannot be totally preprogrammed, each robot must be able to reason for itself. Thus the MIT robotics research addresses unstructured environments both through integrated competences and increased robot intelligence.

The research closely couples theory and experiment in constructing three major integrated robot-system testbeds:

- o A Vision Machine connected to a Head-Eye system,
- o An Integrated Hand-Eye Robot,
- o An Autonomous Mobile Robot equipped with onboard arm.

TITLE

Precision Engineering

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Thomas Dow

(919) 737-3024

North Carolina State University
Department of Mechanical Engineering
Raleigh, NC 27695

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Charles J. Holland

(202) 696-4312

SERVICE

ONR

ABSTRACT

Precision Engineering refers to the technology of inspection and manufacturing at the very limits of measurement. Precision Engineering is a dynamic field moving with the technology of measurement and control. A goal of this research program is to move the technology orders of magnitude below the current level of dimensional accuracies of .0001 inches.

The research is being undertaken by an interdisciplinary team at the newly established North Carolina State University Precision Engineering Center involving professors from the Department of Computer Science, Physics, Materials Engineering, and Mechanical Engineering. This multidisciplinary research team brings together the expertise to develop and apply the concept of real-time control to precision processes. This concept involves the measurement of a dimensional or process error and instantaneously changing the process to reduce the error. In this way inspection can be combined with the fabrication process, guaranteeing components within tolerance without manual intervention.

The potential for real-time control is enormous, but the problems that must be overcome are also formidable. A strategy for solving these problems requires basic research in three areas: control, fabrication, and metrology. The objective is to measure an error, understand the process such that an appropriate correction can be taken, and make that correction before the error exceeds a preselected tolerance. Crucial to this task is speed in computation, correction, and measurement. Whereas this strategy can be applied to any process, it has particular relevance to precision fabrication where small thermal, vibrational, or process change can exceed the allowable tolerance.

TITLE

Center for Manufacturing Science, Reliability, and Maintainability
Enhancement

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Tsu-Wei Chou

(302) 451-8149

University of Delaware
College of Engineering
Newark, DE 19716

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Andrew Crowson

(919) 549-0641

SERVICE

ARO

ABSTRACT

The objective of the initiative in Manufacturing Science is to establish a science base for advanced, automated manufacturing processes for future Army materiel needs. In an effort to fulfill this requirement, the University of Delaware has been selected as a Center to address fundamental issues in manufacturing science, reliability, and maintainability of composite structures. The program is to be integrated into the National Engineering Research Center for Composites Manufacturing Science and Engineering established in 1985 by the National Science Foundation. While the program addresses the entire area of manufacturing, reliability, and maintainability, it strongly emphasizes the goal of building in quality, long life, predictable and reliable performance, durability and lower life cycle costs with a minimum reliance upon repair or rejection of poor quality after manufacture is complete. Research to be supported will include the following:

- o Cure characterization and monitoring,
- o On-line intelligent nondestructive evaluation for in-process control,
- o Process simulation,
- o Computer-aided manufacturing,
- o Structure-property relationships,
- o Mechanics of thick section laminates,
- o Structural performance and durability,
- o Integrated engineering for durable structures

The material forms to be investigated will include both thick section laminates and textile woven forms using both thermosetting and thermoplastic matrix materials. An intern program wherein Army personnel will spend 3 to 18 months in residence at the Center will be implemented along with technical exchange of students, faculty, and staff from the Center to appropriate Army laboratories.

TITLE

Supercomputer Environments

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. David J. Kuck

(217) 333-6223

University of Illinois at Urbana-Champaign
Center for Supercomputing Research and Development
Urbana, IL 61801

ADDITIONAL PARTICIPATING INSTITUTIONS

Indiana University

SCIENTIFIC OFFICER

Capt. John P. Thomas, Jr. (202) 767-5026

SERVICE

AFOSR

ABSTRACT

We are proposing to improve the state of the art in computational environments through work in four major areas:

- (1) Further improvement of smart compilers that are better able to optimize programs for complex, high-performance computers and remove some of the mystery of supercomputer performance, especially for naive users. This work relies on experience with existing supercomputer compilers and with building the most advanced restructuring compilers available.
- (2) Expert systems to help both naive and experienced users design programs for supercomputers, including selection of appropriate routines from extensive libraries of basic algorithms (especially useful for naive users, and automatic evaluation of the numerical quality of the resulting programs).
- (3) Development of a coherent, run-time monitoring and debugging system, including expert debuggers, which will allow faster debugging (and less likelihood that errors will go undetected.)
- (4) Development and integration of techniques for analyzing the user's results, including advanced graphics tools which take advantage of the state-of-the-art graphic hardware available today as well as the power of supercomputers, and an integrated performance measurement capability.

In addition, a large part of the effort involves integration of the new and existing tools into a single, coherent computational environment.

TITLE

Control of Complex Multibody Spacecraft

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. P. S. Krishnaprasad

(301) 454-6866

University of Maryland
Department of Electrical Engineering
College Park, MD 20742

ADDITIONAL PARTICIPATING INSTITUTIONS

University of California at Berkeley, Stanford University

SCIENTIFIC OFFICER

Dr. Marc Q. Jacobs (202) 767-4939

SERVICE

AFOSR

ABSTRACT

An interdisciplinary center of excellence focusing on the control of complex multibody spacecraft will be established. The research program will evolve around two state of the art research laboratories, the Intelligent Servo-mechanisms Laboratory and the Computer Aided Design Laboratory, and will become an integral part of the systems Research Center of the University of Maryland at College Park. Part of the research will be conducted at Stanford University and the University of California at Berkeley.

A program of basic research in the modeling and precision control of large multibody space platforms is proposed. A combination of methods from differential geometry, nonlinear partial differential equations and the input-output theory of distributed parameter systems is needed to deal effectively with control challenges posed by the essential coupling between the nonlinear rigid body dynamics and the multiple elastic components of a large space platform. Computer-aided design methods are needed to translate the "structure-theoretic" formulation of control laws into feedback gains for actuators that fulfill the engineering specifications for the overall closed loop system performance.

In the proposed research program, these analytical and computer-aided tools will be directed toward creating new methods for exploitation of recently developed distributed actuators and sensors under computer control. It is planned to develop bench-marks for selecting controls and configurations that will meet the stringent APT (acquisition, pointing and tracking) requirements for proposed space platforms. Particular attention will be paid to the interaction of control design and structural complexity and models.

TITLE

Center for AI Research

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Victor Lesser

(413) 545-1322

University of Massachusetts
Department of Computer and Information Science
Amherst, MA 01003

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Alan L. Meyrowitz (202) 696-4302

SERVICE

ONR

ABSTRACT

The University of Massachusetts is building a Center of Excellence in Artificial Intelligence (CEAI) to conduct research in four critical areas. Progress in these four areas is essential to the continued success of knowledge-based systems and their applications to real-world problems. Since AI programs derive their power from knowledge, the research is developing methods for machine learning and knowledge acquisition. These include deductive and inductive techniques, as well as interviewing tools and methods to reorganize and update long-term semantic memory structures. Knowledge, once acquired, must be interpreted, though not necessarily by strict logical mechanisms. The second focal point is modes of inference, including nondeductive, case-based, and uncertain reasoning, and also theorem-proving methods. Inference must be controlled, of course, and as knowledge systems get bigger and utilize several modes of inference the need for sophisticated control becomes very pressing. The development of architectures for reasoning explicitly about control is the third focus of the research program. Finally, no knowledge system will be acceptable without an intelligent user interface. It is estimated that over 50% of the effort required to build a useful knowledge system is devoted to the interface. The research therefore addresses problems in natural language, explanation, inferring the user's goals, intelligent help, and tutoring for users.

TITLE

The Infrastructure of Command Information Systems

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Jay Nievergelt

(919) 962-7002

University of North Carolina
Department of Computer Science
Chapel Hill, NC 27514

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Charles J. Holland (202) 696-4312

SERVICE

ONR

ABSTRACT

This research investigates issues in designing and equipping centers for real-time command and control and in constructing prototypes for experimental research into their design. Research issues are being investigated in (1) human computer interactions including the presentation and manipulation of graphical information; (2) communications to integrate a variety of sources and targets of information into a cohesive but flexible system; and (3) decision support systems to provide computational power for the data bases and model on which decisions must be based.

To support human-computer interactions, this project is developing enhanced capabilities to rapidly generate, process and manipulate graphical images. This research builds on extensive experience in building interactive systems including pixel-planes, a highly parallel architecture for the rapid generation of 3-D images. This enhanced graphics capability will be utilized to investigate visual access to data bases replacing conventional graphics by visually guided navigation.

TITLE

Formulation and Programming of Distributed and Parallel Computation

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. J. C. Browne

(512) 471-9579

University of Texas at Austin
Department of Computer Science
Austin, TX

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Charles J. Holland (202) 696-4312

SERVICE

ONR

ABSTRACT

The theme of this work is advanced research in formulation and programming of distributed and parallel computations. Emphasis is placed on carrying out fundamental ideas in programming environments, exploration of parallel execution environments, and experimental applications. Exploration of major new research concepts is being initiated, including extension of programming techniques for conventional software to techniques for transforming software specifications of digital system functionality to produce chip designs. A major activity of the first year of the program is a "Year of Programming" to focus national research efforts in parallel and distributed computing.

Programming includes all aspects of creating an executable representation of a problem through all levels of abstraction from mathematical formulation to representation of an algorithmically specific architecture in a hardware description language. Aspects of this process which have been identified for attention include problem formulation, specification languages, programming languages, presentation languages, and the transformation among these many representations. The Year of Programming attempts to identify and address the subset of these problem domains and issues which are bottlenecks to progress towards the conversion of programming into a mathematical and tool supported discipline and one which extends from high levels of abstraction to computer architecture.

The research being done is motivated by the recognition that programming in the broad sense given above is the central problem which unites all of computer science and much of computer engineering. There is a rising recognition of the commonality of the problems which occur in programming at all levels of abstraction and in the need to both place each level on a sound definitional and mathematical foundation and to seek such unification as may lead to more effective transformations between programs expressing computations at different levels of abstraction.

C. SUBMICRON STRUCTURES

Services' Areas of Emphasis:

High-Frequency Microelectronics (ARO)

Ultra Submicron Electronics (ONR)

Structured Electronic Materials and Devices (AFOSR)

Submicron Structures Research (DARPA)

TITLE

II-VI Microstructures

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. T. C. McGill

(818) 356-4849

California Institute of Technology
MS 128-95
Pasadena, CA 91125

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Arati Prabhakar

(202) 694-3145

SERVICE

DARPA

ABSTRACT

The development of optical components for detectors or sources of visible radiation requires applications of recently developed growth techniques to the fabrication of semiconductor heterostructures using the II-VI compounds. The characterization of these structures and consideration of their properties for use in optical and electronic devices will be explored.

MBE techniques will be used to grow layered structures involving various II-VI compound semiconductors. Strained and unstrained superlattice structures will be grown and their structural, optical and electronic properties characterized using various techniques, such as optical absorption, high field transport, photoluminescence, Rutherford backscattering, x-ray diffraction, Raman scattering, I-V, C-V, and DLTS. Choice of appropriate substrates and critical materials for a given requirement of optical properties (detector or source) will be guided by using computer simulation methods to predict bandgaps, quantum states, transport coefficients, and other properties of the superlattices.

TITLE

Interfacial and Thin Film Chemistry in Electron Device Fabrication

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. R. M. Osgood

(212) 280-4462

Columbia University
Department of Electrical Engineering
New York, NY 10027

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Max N. Yoder (202) 696-4218

SERVICE

ONR

ABSTRACT

This block program combines experts in chemistry, applied physics, and electrical engineering in a multidisciplinary investigation of a critically important area for future electronic integrated circuits: growth kinetics, processing, and properties of semiconductor/metal/insulator surfaces and interfaces.

Columbia has formed an interdisciplinary research group to investigate prominent classes of interfacial reactions which are important in the fabrication of submicrometer electronic circuits and devices. It brings together a highly talented team with expertise in chemistry, applied physics, and electrical engineering. The combination of chemistry expertise with state-of-the-art materials fabrication and characterization and electronic device characterization is unique and extremely promising. The Molecular Beam Epitaxy (MBE) work is particularly noteworthy. A new machine has been purchased, which will contain not only a variety of in situ characterization tools for studying MBE growth kinetics, impurity and defect incorporation, and surface structure, but will also contain a C.W. laser for illuminating the growth surface in order to stimulate optically-induced growth phenomena.

The investigators have strong credentials in the areas of chemistry, applied physics, and electron device physics. Richard Osgood, of the Electrical Engineering Department, is well-known for interdisciplinary work encompassing both electronic materials processing and fundamental chemical physics. Irving Herman joined the Columbia Applied Physics Department in the fall of 1986 from Lawrence Livermore Laboratory, where he was a research group leader and active in developing new optical diagnosis techniques for semiconductor processing. Nicholas Turro, of the Chemistry Department, is highly regarded in the field of organic surface chemistry, and is a member of the National Academy of Science. He has recently turned his attention to the subject of chemistry of electronic materials, and this proposed program is a tremendous opportunity to couple a chemist of his stature to people working in the electronics area. George Flynn

is a well-known pioneer in the application of lasers to the study of chemical phenomena. Wen Wang will join the Electrical Engineering Department at Columbia in early 1987 from IBM, Yorktown Heights. Dr. Wang is a young investigator who has already developed a solid reputation in MBE growth and quantum-well physics. Eric Fossum, of the Electrical Engineering Department, was recently designated an NSF Presidential Young Investigator, and is specializing in ion-beam formation of ultrathin oxides. Edward Yang, of the Electrical Engineering Department, specializes in electronic studies of semiconductor/metal surfaces and interfaces, and has recently developed a novel interface diagnostic technique.

TITLE

Nanocomposites for Electronic Applications

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. L. Eric Cross

(814) 865-1181

Pennsylvania State University
251A Materials Research Laboratory
University Park, PA 16801

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Kay Rhyne (202) 694-1303

SERVICE

DARPA

ABSTRACT

The proposed research will fabricate and characterize a new class of electro-active composite materials, called nano-composites, with internal spacings in the range of 5 to 500 nanometers. With such fine spacings, these materials should find numerous applications in optical devices requiring electro-optic, magneto-optic, acousto-optic, and nonlinear optic properties. This effort will lay the foundations in processing studies which will permit the fabrication of a wide range of nano-composite structures with the eventual objective of being able to control phase self-connection in three dimensions. It is the intention to explore one, two, and three dimensional composites involving nano-thickness plates, nano-diameter rods, and three dimensionally comminuted composites. The effort will build upon the research expertise of Penn State University in successfully fabricating piezoelectric composites which require much coarser structures.

TITLE

Dilute Magnetic Semiconductor Heterostructures

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Anant K. Ramdas

(317) 494-3028

Purdue University
Department of Physics
West Lafayette, IN 47907

ADDITIONAL PARTICIPATING INSTITUTIONS

University of Notre Dame, Harvard University, Massachusetts Institute of Technology, North Carolina State University, Brown University

SCIENTIFIC OFFICER

Dr. Jim Murphy (202) 694-1303

SERVICE

DARPA

ABSTRACT

This program brings together most of the expertise within the United States in the field of Dilute (or Semi) Magnetic Semiconductors (DMS) for the purposes of fundamental materials and device research and investigation of potential DoD applications. These materials are unique in that they are semiconductors and yet have magnetic properties. This offers the possibility of new multilayer electronic devices and monolithic integration with other devices based on semiconductors such as Si, GaAs, and HgCdTe. Most of the work in these materials up to now has been performed outside the U.S., predominantly in Poland. This is the first major U.S. research program in DMS materials.

The essential program elements are bulk crystal and thin film growth and characterization, theoretical and experimental studies of the physical properties (electronic, mechanical, optical, and magnetic) of DMS materials, and device research. The thin film growth techniques are atomic layer epitaxy (ALE), and molecular beam epitaxy (MBE). Device research will encompass growth of multilayer structures (eg., superlattices) and systematic doping experiments in a variety of II-VI materials, development of device processing techniques and of metal-semiconductor ohmic and Schottky barrier contacts, and fabrication and characterization of devices.

Potential applications include high performance magneto-optical devices operating over a very wide wavelength regime, from the blue end of the visible to long wave infrared. Candidate devices already identified are optical isolators and circulators, magnetic phase shifters, switches, modulators, frequency discriminators, and magnetometers. Systems that could benefit from these components include optical communications, optical recording, optical computing, and optical radar. Of special interest is the possibility of developing reliable blue or blue-green injection lasers with many applications such as satellite to submarine communications.

TITLE

Center for High Frequency Microelectronics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. George I. Haddad

(313) 764-7139

University of Michigan

Department of Electrical Engineering and Computer Science

Ann Arbor, MI 48109-1109

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Michael A. Strosio

(919) 549-0641

SERVICE

ARO

ABSTRACT

The University of Michigan Center for Research on High-Frequency Microelectronics has the objective of enhancing the Army technology base in several critical areas of defense-related high-frequency microelectronics. The University Research Initiative (URI) Program at the Center will focus on theoretical and experimental interdisciplinary research topics that include:

- o Carrier transport phenomena,
- o Dissipative interactions in solid-state electronic materials,
- o Electronic properties of subdimensional structures and heterojunctions,
- o High mobility transport in electronic structures,
- o Velocity overshoot,
- o Non-equilibrium phenomena in solid state electronic materials,
- o Phenomena controlling light-hole conduction near epitaxially-grown heterojunctions, and
- o Quantum transport.

Progress in these research areas is essential to realizing envisioned devices that include:

- o Submicron field effect transistors,
- o High-electron-mobility transistors,
- o Ballistic transistors,
- o Quantum well oscillators and resonators,
- o Two terminal millimeter wave devices, and
- o Optoelectronic devices for high data rate communication and signal processing systems.

The University of Michigan will interact with Army research and development organizations in accomplishing the Center's research objectives.

TITLE

Ultrafast Optical Electronics Center

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Gerard A. Mourou

(716) 275-2092

University of Rochester
Laboratory for Laser Energetics
Rochester, NY 14623-1299

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Gerald L. Witt (202) 767-4931

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - Under the direction of Prof. Mourou, ultrafast optical techniques have been developed permitting the characterization of electronic processes on a sub-picosecond time scale. In this URI Center, Mourou's team will utilize these techniques to examine fundamental physical interactions in electronic materials and devices. Such studies require state-of-the-art semiconductor materials and devices; these will be provided by the research team at Cornell University headed by Prof. Eastman.

One research topic is an examination of the tunneling from quantum wells formed with thin layers of compound semiconductors. A series of special test structures will be produced at Cornell that will permit the measurement of time-resolved resonant and non-resonant tunneling from single quantum wells. The modeling of such tunneling will be done by collaborators in the Physics Department at Rochester.

Also in collaboration with Cornell is a study of the ballistic injection of electrons. This effect will be examined in a variety of transistor configurations including doped base transistors, induced base transistors, and negative resistance field effect transistors. The objective is to develop an understanding of the energy loss mechanism and the real space transfer of hot electrons.

Another project is studying the question of velocity overshoot in semiconductor structures. The optical measurements at Rochester will be made in collaboration with modeling work at Arizona State University.

D. BIOTECHNOLOGY

Services' Areas of Emphasis:

Biosystems and Biotechnology (ARO)

Marine Bioengineering (ONR)

Biological Structure/Material Properties (DARPA)

TITLE

Biopolymers: Proteins and Nucleic Acids

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Jack Richards

(818) 356-6040

California Institute of Technology
Department of Chemistry and Biology
1201 East California Blvd.
Pasadena, CA 91125

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Ira Skurnick

(202) 694-3145

SERVICE

DARPA

ABSTRACT

This will be an interdisciplinary program under the DARPA URI program on interactions between proteins, synthetic reagents and drugs, and nucleic acids. The interactions of nucleic and proteins serve as a useful paradigm for gaining insights into the principles that generally govern interactions between polymers and therefore determine the properties of many materials. A strong component of the research is for the purchase of equipment and the support of graduate students and postdoctoral scholars.

Specifically the research will include: (1) Studying the interactions between proteins and nucleic acids which play a central role in such fundamental processes as replication, differentiation, control of gene expression, processing of genetic information and the translation of genetic information; (2) to gain an insight into principles that govern interactions between polymers and thereby determine the properties of many materials; (3) to do theoretical and graphical studies on biopolymers; (4) to do structural and dynamical studies using NMR; (5) to train a cadre of well trained students and postdoctoral scholars in molecular biological aspects of biotechnology.

Scientists from the Chemistry and Biology Departments will use methodologies developed at Caltech that allow a comprehensive and uniquely synthetic approach to studies on biological structure and material properties.

TITLE

Center for Biosystems and Biotechnology

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Gordon G. Hammes

(607) 255-2300

Cornell University
Department of Chemistry
Ithaca, NY 14853-2801

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Shirley Tove (919) 549-0641

SERVICE

ARO

ABSTRACT

A Center in Biotechnology will be established within the Cornell University Biotechnology Program. The research focus of this Center is protein structure and function, with special emphasis on enzymes and receptors. The research is a multidisciplinary attack on the molecular basis of how proteins and enzymes work, how energy and enzymic processes are coupled through cell membranes, how membrane receptors are used to transmit signals to the cell, and how signals are transmitted in the nervous system. The Center is governed by a Scientific Administrative Board. The specific projects supported are chosen on a competitive basis from proposals submitted by faculty members. Twenty faculty are involved initially in the research of the Center. Examples of specific projects that would be supported are the following:

- o Computer-based calculations of protein structure and the mechanism of protein folding;
- o X-ray crystallography of proteins and hormones;
- o Development of immobilized enzyme systems;
- o Genetic engineering of enzymes and microbial cells;
- o ATP synthesis by chloroplasts and the coupling of ion gradients to enzymic activity;
- o The mechanism of action of multienzyme complexes;
- o Enzymic modification of membrane proteins and the control of cellular metabolism;
- o The triggering of cellular processes by binding to membrane-bound receptors;
- o The role of calcium in receptor triggered cellular responses;
- o The coupling of toxicity to permeability changes in mammalian cells;
- o Structure, function and regulatory properties of acetylcholine receptors;
- o Neurotransmitters, receptors and ion channels in the nervous system.

Research participants come from the departments of Chemistry, Biochemistry, Molecular and Cell Biology, Chemical Engineering, Plant Biology, Pharmacology, Applied and Engineering Physics and Neurobiology and Behavior. Army personnel (with appropriate scientific background) will be given an appointment at Cornell for an agreed upon period of time to do research. Retraining in a new field of research can be arranged. Cornell faculty are available to present seminars at the Army laboratories upon request.

TITLE

Synthesis and Study of Ultra-Small Structures and Devices Derived from Molecular Materials

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. George M. Whitesides

(617) 495-9430

Harvard University
Department of Chemistry
Cambridge, MA 02138

ADDITIONAL PARTICIPATING INSTITUTIONS

Massachusetts Institute of Technology

SCIENTIFIC OFFICER

Dr. Ira Skurnick (202) 694-3145

SERVICE

DARPA

ABSTRACT

This research will have two foci, both involving the development of ultrasmall structures. One will involve self-assembled organic monolayers, prepared by absorption of functionalized organic molecules on solid metal semiconductor or insulator surfaces. These systems will be used as the basis for studies of wetting, adhesion, and electron tunneling. The second will involve the synthesis and characterization of assemblies designed to achieve functions analogous to those found in biological and electronic systems and will emphasize the preparation of functionalized microelectrode arrays. The project will also acquire four major pieces of apparatus for a joint facility in surface science: RBS, XPS, Auger, and SIMS.

TITLE

Protein Design and Function

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Robert Langridge

(415) 476-2630

University of California at San Francisco
Computer Graphics Laboratory
School of Pharmacy
San Francisco, CA 94143-0446

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Ira Skurnick (202) 694-3145

SERVICE

DARPA

ABSTRACT

This research will: (1) develop heuristic methods for sequence comparisons and prediction of secondary and tertiary structures, (2) develop methods of distance geometry to permit prediction of structures in a model independent manner, (3) develop molecular mechanics and dynamics algorithms to describe physical interaction energies, (4) develop statistical mechanical and combinatoric and topological methods for accounting for the constraints and the entropic degrees of freedom available to the polymer chains, and (5) develop applications of these methods.

Scientists from the computer graphics laboratory, biophysics and pharmaceutical chemistry department will collaborate closely in this endeavor. The program involves substantial equipment investment in year one and training of graduate students in all of the years. A close collaboration exists with NRL.

TITLE

Molecular Genetics and Molecular Biology of Marine Organisms

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Rita Colwell

(301) 853-3601

University of Maryland
Center for Marine Biotechnology
Adelphi, MD 20783

ADDITIONAL PARTICIPATING INSTITUTIONS

Johns Hopkins University

SCIENTIFIC OFFICER

Dr. Robert W. Newburg (202) 696-4986

SERVICE

ONR

ABSTRACT

This research brings together marine biologists and molecular biologists to exploit the use of marine organisms in biotechnology. The scientists involved are from the University of Maryland and Johns Hopkins University. They are using: (1) recombinant DNA techniques to clone functional genes of marine bacteria into non-marine bacteria; (2) spectro-photometric, NMR, and x-ray crystallography to determine the structural differences between proteins, nucleic acids, polysaccharides and lipids from organisms that grow at high temperature and pressures and those grown at normal temperatures and pressure; (3) genetic analysis to develop expression gene banks for marine organisms. Such approaches will lead to: (1) an understanding of the molecular mechanisms of interactions amongst marine organisms responsible for biofouling and biocorrosion; (2) the determination of structure/function relations in macromolecular and membranes produced by bacteria growing in extreme environments; and (3) an understanding of gene regulation in marine organisms. The program involves substantial equipment investment in year one and training of graduate students and post-doctorals in all of the years. It is anticipated that this will fill a much needed requirement for scientists trained in molecular marine biology. A close collaboration exists with NRL.

E. ELECTRO-OPTIC SYSTEMS AND SIGNAL ANALYSIS

Services' Areas of Emphasis:

Electro-optics, Signal Processing and Image Understanding (ARO)

Free Electron Laser Research Opportunities (ONR)

X-ray Sources/Optics (AFOSR)

Opto-Electronics and Optical Processing (AFOSR)

TITLE

Center for Electro-optics and Plasma Research

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Demetries Venable

(804) 727-5277

Hampton University
Physics and Engineering Department
Hampton, VA 23688

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Howard R. Schlossberg (202) 767-4906

SERVICE

AFOSR

ABSTRACT

Hampton University is conducting state-of-the-art research on high power near ultraviolet (uv) laser systems and high current switches. The University will establish fellowships.

TITLE

Advanced Source Development and Applications

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. E. I. Lindau and Dr. J. M. J. Madey

(415) 725-2185

Stanford University
Electrical Engineering Department
Stanford, CA 94305

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Howard R. Schlossberg (202) 767-4906

SERVICE

AFOSR

ABSTRACT

Stanford University is studying and developing advanced ultraviolet, extreme ultraviolet, and soft X-ray synchrotron radiation and laser plasma sources, beamlines and instrumentation and applying these systems for research in electronic materials and devices, surface chemistry, solid state physics, and biomedicine.

TITLE

Laboratory for X-Ray Optics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. R. Shannon and Dr. C. Falco

(602) 621-6998

University of Arizona
Optical Sciences Center
Tucson, AZ 85721

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Howard R. Schlossberg

(202) 767-4906

SERVICE

AFOSR

ABSTRACT

A Laboratory for X-Ray Optics is being created at the University of Arizona. The work being conducted consists of research on multilayer coatings of x-ray optical elements, design and construction of appropriate fabrication and characterization instrumentation, and training of graduate students and visiting scientific personnel in this field.

TITLE

X-Ray Optics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. T. Atwood

(415) 486-4000

University of California at Berkeley
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

ADDITIONAL PARTICIPATING INSTITUTIONS

University of California at San Francisco, State University of New York
at Stony Brook, University of Rochester, University of Wisconsin at
Madison

SCIENTIFIC OFFICER

Dr. Howard R. Schlossberg

(202) 767-4906

SERVICE

AFOSR

ABSTRACT

X-ray optical components and scientists trained to use them are critically needed to exploit the rapid development of new sources of extreme ultraviolet and x-ray radiation. Components such as multilayer mirrors, zone plate lenses, dispersive gratings, beam splitters, etc., are needed as end-mirrors for free electron and atomic lasers, lenses for collimation and focusing, high resolution zone plate lenses for microscopy, microanalysis and microholography, and new high resolution dispersive systems for use in spectroscopic and interferometric applications for both the pure and applied sciences. This proposal addresses both scientific experimentation with new x-ray techniques and the training of university students in this important new area of science and technology.

TITLE

Low Voltage Free Electron Laser

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Luis Elias

(805) 961-4434

University of California at Santa Barbara
Center for Free Electron Laser Studies
Quantum Institute
Santa Barbara, CA 93106

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Robert E. Behringer (818) 795-5971

SERVICE

ONR

ABSTRACT

The University of California, Santa Barbara URI consists of three strongly interrelated efforts -- a coordinated effort to improve upon the present characteristics of the UCSB FEL to extend its operation to the infrared, to provide a high power, narrowband source from 10 micrometers to 1000 micrometers, and to test new FEL concepts; to use this unique radiation source in a broadly based scientific program involving biomedical, biophysical, chemical, and condensed matter science; and to train graduate students and postdoctoral fellows in both FEL technology and its application to forefront scientific research.

High power continuously tunable radiation sources do not exist in the 20 micron to submillimeter wave region. Pumped molecular lasers exist in this region, however, they are not continuously tunable across this region and the output powers are limited. The FEL as it now exists at the UCSB has demonstrated tunability between 100 and 800 microns with output power in excess of 20KW for pulse lengths up to 40 microseconds. The two-stage configuration now being assembled should produce lasing down to micron wavelengths. Since the existing single stage FEL can operate to wave-lengths of 1000 microns, the current FEL will be capable of continuously tunable operation from several microns to 1000 microns. In addition, the long electron pulses lead to a frequency bandwidth more than four orders of magnitude narrower than that of any other FEL. An extensive FEL research program has been defined which can lead to significant improvement in the FEL operation, enhancement of output capabilities, and demonstration of new FEL concepts. These FEL experiments include concepts for undulators, electron sources, and two-beam two-stage FEL devices. In the two-stage two-beam experiment, it is proposed to use the 3 mm radiation from one FEL to set up a standing wave which would generate FEL output in the 10 to 100 micron range by scattering from the second electron beam. This would extend the high power tunable radiation from 10 to 1000 microns, i.e., narrowband tunable radiation over two orders of magnitude. Additional undulator concepts are proposed to obtain radiation into the optical region with the same electron beam.

Being a totally unique source of high power radiation in the IR to FIR region and being user-oriented, it has attracted considerable interest from the biophysical, biomedical, chemistry, and condensed matter communities both within the U.S. and abroad. Biomedical experiments to determine the wavelength and power dependence of the inactivation of a number of different types of cells and the mechanisms involved are proposed to determine the possibility of selectively disrupting certain cells. The tunability of this FEL will permit the study of the excitation of the hydrogen bond stretching modes in the 65-100 cm^{-1} FIR region which are thought to be involved in the transcription and replication of DNA. Many collective modes (e.g., phonons magnons) in solids are found in the IR to FIR. Studies which will ultimately be applicable in highspeed electronic and opto-electronic devices include nonlinear behavior in the cyclotron resonance of high mobility GaAs-GaAlAs heterojunctions in two-dimensional electron systems. The dynamics of impurity associated local modes, that is, the coupling between impurity local modes and the continuum of host excitations, could be directly investigated in detail now.

TITLE

Optoelectronics Research Center

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. W. Streiffer

(505) 277-6033

University of New Mexico
Center for High Technology Materials
102 Scholes Hall
Albuquerque, NM 87131

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Howard R. Schlossberg (202) 767-4906

SERVICE

AFOSR

ABSTRACT

In the near term, 1-2 years, LPE and MO-CVD are being used to grow (GaAl)As, characterize the wafers, fabricate and assess semiconductor lasers and arrays, and perform experiments to injection lock and otherwise control and combine the laser outputs. Diagnostic techniques for both materials and device characterization are being investigated. Initial experiments at integrating optical and electronic components are being undertaken. Improved devices based on novel concepts and materials, including MO-CVD grown phosphorus-containing alloys, will be studied in the intermediate term (2-3 years). Examples are disordering of multiple quantum-wells to modify refractive index and bandgap, the use of gratings, the larger-scale integration of sources, waveguides, modulators, beam deflectors, and electronic components. Over the longer term, 3-5 years, research will be performed based on innovative device ideas and new III-V, II-VI, organic, and "bandgap engineered" materials to extend the wavelength ranges of both sources and detectors, nonlinear optical devices for optical computing and other applications, and Opto-Electronic Integrated Circuits to exploit the greater capabilities inherent in integration.

TITLE

Center for Electro-Optics, Signal Processing, and Image Understanding

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Nicholas George

(716) 275-2417

University of Rochester
The Institute of Optics
Rochester, NY 14627

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Bob D. Guenther (919) 549-0641

SERVICE

ARO

ABSTRACT

A primary goal for the Center for Electro-Optics, Signal Processing and Image Understanding is to contribute fundamental scientific knowledge in the key technology areas common to these systems, e.g., lasers, modulation, optical system design, propagation and coherence, detection theory, signal processing, digital methods, and displays. The Program Director, working with a Systems Integration Team, will relate research findings to Army needs and interactively plan each year's research guided by mission requirements. The professional staff includes a unique, cross-disciplinary group of 13 faculty from the Institute of Optics, together with 20 doctoral fellows. A list of topics includes:

- o Image retrieval and automatic pattern recognition,
- o Digital image processing for human and machine vision,
- o Scattering from fluctuating media,
- o Optical aberration coefficients applied to system design,
- o Innovative optical coating techniques and instrumentation,
- o Guided wave optics,
- o Nonlinear optics and optical phase conjugation,
- o X-ray optics, XUV spectroscopy of slowly autoionizing levels,
- o Coherence properties of stimulated Raman scattering,
- o Instabilities and dynamics of laser systems,
- o Electrically pumped color center lasers.

TITLE

Center for the Integration of Optical Computing

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. William H. Steier

(213) 743-0149

Prof. Alexander Sawchuck

(213) 743-5527

University of Southern California

Department of Electrical Engineering and Electrophysics

Los Angeles, CA 90089-1147

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. C. Lee Giles

(202) 767-4931

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - Optical computing has great potential for solving the computationally demanding problems of future military systems and industrial automation, but the critical, missing technology for the practical realization of this potential is the ability to integrate the optical and electronic components in a single materials system or in a compact hybridized system. Thus, the goal of this proposed research is to develop system architectures and algorithms, devices and device processing technology leading to monolithic or hybrid integration of optical computing systems. Achieving this goal will require the synergistic interaction between systems, devices, and materials scientists so that the algorithms and architectures are developed with an awareness of the state-of-the-art of device integration, and the device research is keyed to the needs of the systems studies. The creation of this proposed Center and the associated industrial support will establish a strong, continuing interaction among the several faculty at USC who are actively involved in research on the various aspects of optical computing. Through this interaction, a "critical mass" of research participants will occur through the sharing of research facilities, creation of thirteen new joint research projects, establishment of seminars and lecture series, and encouragement of scientific and technical exchanges with Air Force Laboratory and industrial personnel. APPROACH - The specific research projects are divided into two major categories: hybrid optical-electronic computing systems and all-optical computing systems. The most promising materials system for monolithic integration is the GaAs based compound semi-conductors and, therefore, the device and materials projects are centered around these materials. The hybrid optical-electronic projects take best advantage of the complimentary capabilities of optics (efficient linear operations and communications) and electronics (efficient nonlinear operations). The hybrid projects include: optical/VLSI parallel processing algorithms and architectures; dynamically reconfigurable optical interconnection networks; high sensitivity optical detector arrays; low threshold optical array sources; and waveguide-

coupled photodiode arrays. The all-optical computing projects take advantage of the parallelism, inherent high bandwidth, reduced interference, and reduced interconnection delay characteristics of systems in which photons are the primary information-carrying medium. The all-optical computing projects include: optical processors for neural computation of image understanding algorithms; compact parallel digital optical processors; contention-free parallel optical access to binary arrays; nonlinear Fabry-Perot spatial light modulators; all-optical associative memories; tag-controlled opto-optical switching; MBE growth and characterization of multiple quantum well devices (MQW); volume holographic elements and spatial light modulators using MQW structures.

F. HIGH PERFORMANCE MATERIALS

Services' Areas of Emphasis:

- Ultra Dynamic Performance Materials (ARO)
- Advanced Construction Technology (ARO)
- Composite Materials (ONR)
- Advanced Electrical and Structural Polymers (AFOSR)
- High Temperature Structural Materials (AFOSR)
- Surface and Thin Film Sciences (AFOSR)
- Cement Paste Matrix Composite Materials (AFOSR)
- Lightweight, Flexible Structures (AFOSR)
- High Temperature Structural Composites (DARPA)
- Structural and Electronic Polymers (DARPA)

TITLE

Center for Organosilicon Polymers

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Mukund Sibi

(404) 681-0251, ext 346

Atlanta University
Department of Chemistry
J. P. Brawley Drive, N.W.
Atlanta, GA 30314

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Donald R. Ulrich (202) 767-4963

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - This research program will synthesize and study organosilicon polymers containing the bicyclo[2.2.2]octane ring system with the expectation that the thermal stability of certain organosilicon polymers can be combined with the rigid rod structure of the bicyclo[2.2.2]octane framework to produce thermotropic liquid crystalline properties. The electrooptic properties will be characterized.

APPROACH - The first part of the program is concerned with the preparation of polysiloxanes with side chains containing the bicyclo[2.2.2]octane structure. The length of the aliphatic side chain will be varied, as will the number of bicyclic units in order to achieve optimum properties. The second phase of the program will synthesize bicyclo[2.2.2]octane which contain one or two silicon atoms at the bridgehead positions. These compounds will be used in the synthesis of additional polysiloxanes containing side chain bicyclic units. Linear polymers in which both the silicon-oxygen bond, and the bridgehead silicon bicyclic system are part of the main chain will be synthesized. Polysilanecarboxylic esters will be prepared, where it is presumed that the corresponding silanecarboxylic esters will have liquid crystalline properties.

TITLE

Metal-Matrix Composites for High-Temperature Structures

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Anthony W. Thompson

(412) 268-2711

Carnegie Mellon University
Metallurgical Engineering
Pittsburgh, PA 15213

ADDITIONAL PARTICIPATING INSTITUTIONS

University of California at Berkeley, Clemson University

SCIENTIFIC OFFICER

Dr. Alan H. Rosenstein

(202) 767-4933

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - An extensive research effort on high-temperature structural materials will be undertaken by a team of investigators at Carnegie Mellon University and at subcontracting institutions. The focus of the work is on metal-matrix and intermetallic-matrix composites, with ceramic reinforcement phases of particulate or of short-fiber character, prepared in most cases by powder metallurgical processes. The work includes studies of processing, resulting microstructures, and corresponding properties at ambient and elevated temperature. The goal is broad understanding of both development of microstructure, and of microstructural control of properties, in composite materials for high-temperature structural applications. APPROACH - the research comprises three aspects. First, processing of metal-matrix composites (atomization, blending, fabrication); second, detailed characterization of microstructure and local composition, particularly at matrix-reinforcement interfaces; and third, examination and understanding of mechanical properties (toughness, fatigue, creep, stress rupture, and combinations of these). Metal-matrix composites have been chosen, in part, to address the roles of reinforcement properties and of interfaces in a more detailed and explicit way. The ceramic reinforcement phases in these composites will be of particulate or of short-fiber character, since these reinforcements result in materials which exhibit relative ease of fabrication and reduced anisotropy for a broad range of applications. Any experimental program in composite materials requires a source of good-quality materials which can not only be characterized as to processing details, but which also can be produced in varying ways to suit the needs of the experimental program as it develops. For that reason, the work includes both research into processing aspects of material behavior, and also contributions by laboratories which will produce material for experimental use.

TITLE

Structural, Mechanical and Bonding Aspects of Interphase Interfaces in High-Temperature Structural Composites

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. A. H. Heuer

(216) 368-3868

Case Western Reserve University
Department of Metallurgy and Materials Science
Cleveland, OH 44106

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Phil Parrish

(202) 694-1303

SERVICE

DARPA

ABSTRACT

Interface interphases in high temperature structural composites, both metal matrix and ceramic matrix, will be studied in four separate but related thrust areas:

1. High resolution electron microscopy (HREM) studies of interfaces,
2. Quantum mechanical calculations of the interfacial bonding and adhesion,
3. Mechanical characterization of manufactured metal-ceramic and ceramic-ceramic interfaces, and
4. Surface physics studies of the structure, bonding and chemistry of interfaces.

The HREM study will establish geometrical models to describe interphase interfaces. Metal-ceramic interfaces between Al_2O_3 and metals such as Pt, Ti and Ni and ceramic-ceramic interfaces such as $\text{Al}_2\text{O}_3/\text{SiC}$ and $\text{SiC}/\text{Si}_3\text{N}_4$ are of interest. In addition, ion-beam mixing and direct ion implantation will be used to create graded interfaces whose structure and properties will be studied.

Quantum mechanical calculations will provide a theoretical framework to understand the relationship between structure and adhesive energy. Both molecular orbital cluster theory and self-consistent ab initio calculations of interfaces will be used.

The strength and fracture mechanics of interfaces as a function of structure and chemistry, i.e., processing parameters, will be determined. Various metal/ceramic interfaces will be selected and manufactured and their fracture toughness evaluated. Numerical finite element calculations will be used to determine the stress field in failed specimens, using the actual geometry of the fracture surface. Indentation fracture mechanics on thin deposited films and also on diffusion bonded joints is another part of this investigation.

The bonding of "model" systems which are clean (i.e., impurity-free) and smooth will be studied by depositing metals onto Al_2O_3 single crystal substrate and techniques such as HREELS, UPS, XPS, LEED will be used to study bonding as a function of film thickness from submonolayers to multilayers. A surface science study of the fractured interface of real composites will also be performed. Direct force-elongation measurements will be done on very thin samples in which the interfacial region occupies a significant fraction of the sample volume; this technique will be extended to strain layer superlattices. The interfacial adhesion in a matrix will be measured directly, after which surface science characterization of the fibers and the matrix holes will be made.

TITLE

Control of Flexible Structures

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Francis Moon

(607) 255-7146

Cornell University
Department of Theoretical and Applied Mechanics
Thurston Hall
Ithaca, NY 14853-1503

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Tony Amos (202) 767-4937

SERVICE

AFOSR

ABSTRACT

Description: An interdisciplinary effort, incorporating analytical, computational and experimental activities is being undertaken to systematically identify those conditions under which the dynamic behavior of complex structural systems transition from the classical vibration paradigm into more complex possibly chaotic response. A variety of experiments ranging from studies of simple desk top models to tests of full scale sized components are being conducted. Nonlinear models will be developed and refined for agreement with experimental observations. Nonlinear simulation approaches will be developed for the controlled dynamics of flexible systems.

TITLE

Center for Advanced Construction Technology

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Fred Moavenzadeh

(617) 253-7178

Massachusetts Institute of Technology
Center for Construction Research and Education
Cambridge, MA 02139

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Gary Anderson (919) 549-0641

SERVICE

ARO

ABSTRACT

The Center for Advanced Construction Technology at Massachusetts Institute of Technology will seek to enhance the productivity and capabilities of construction resources essential to the support of the Army's mission through programs of research, fellowship awards, equipment acquisition and information and personnel exchange. Research projects will focus on areas where recent technological advancements have high potential for successful application to military construction. These include:

- o Materials and structures
- o Computers
- o Automation and robotics
- o Methodology related to facility performance, reliability, and maintainability
- o Life-cycle costing

The equipment acquisition program will provide a permanent and unique set of experimental facilities essential to the continued advancement of these technologies. Mechanisms for the exchange of scientific knowledge include: an advisory board; publications distribution, meetings, conferences, and symposia; continuing education seminars; and exchange of faculty and staff between Army laboratories and MIT.

The development of human resources with interest in, and technical capabilities for, continued technological advancement and transfer will be accomplished through the fellowship program and through funding the research activities of MIT faculty, research staff, and students.

TITLE

Mechanical Properties of Structural Polymers

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Ali S. Argon

(617) 253-2217

Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Kay Rhyne (202) 694-1303

SERVICE

DARPA

ABSTRACT

The mechanical properties of polymers in both glassy and crystalline form play increasingly key roles in structural members by themselves, and in conjunction with reinforcing phases in composites. These properties depend intimately on the molecular and supra-molecular structure of these polymers. The conformational and morphological states and their changes upon aging and in large strain inelastic deformation are topologically complex processes which are now amenable to computational modeling to develop quantitative understanding and appropriate physically-sound scaling laws.

In this long-range research program, fundamental understanding is sought through computational modeling of the molecular level processes in plastic deformation, in early phases of cavitation under stress, for time dependent structural relaxations in the glassy state, and for texture evolution in large strain deformation in semi-crystalline polymers. In a closely allied fourth task, the process of texture evolution in semi-crystalline polymers will be studied experimentally by a number of diffraction and scattering techniques.

TITLE

Accelerating the Advancement of Composite Materials Research Through a Satellite Network

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Lionel V. Baldwin

(303) 491-1632

National Technological University
P.O. Box 700
601 S. Howes Street
Fort Collins, CO 80522

ADDITIONAL PARTICIPATING INSTITUTIONS

Collaborating with the consortium of universities led by the University of Illinois (see page 82).

SCIENTIFIC OFFICER

Dr. Alan S. Kushner

(202) 696-4305

SERVICE

ONR

ABSTRACT

The National Technological University (NTU) operates an Instructional Television (ITV) network linking more than twenty universities with corporate R&D and production facilities throughout the United States. Through their ITV program, a student may enroll in selected courses from any participating university and earn a master's degree from NTU. All of the courses would be taken at the student's place of work with direct two-way audio communication between the student and the teacher. The objective of the current investigation is to expand the ITV concept to encompass research interactions between researchers at different universities studying similar or interrelated problems. All of the participants in the ONR URI Composites area will be connected into the NTU network. A series of research seminars, advanced topics courses, and program reviews will be broadcast to all participants in the program. In addition, Navy laboratories and industrial participants will be able to link-up to the NTU system to participate in the program.

TITLE

Micro/Macro Studies of Fiber-Reinforced Composite Materials

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. V. Sarma Avva

(919) 379-7620

North Carolina A & T State University
Department of Mechanical Engineering
108 Graham Hall
Greensboro, NC 27411

ADDITIONAL PARTICIPATING INSTITUTIONS

Collaborating with the consortium of universities led by the University of Illinois (see page 82)

SCIENTIFIC OFFICER

Dr. Alan S. Kushner

(202) 696-4305

SERVICE

ONR

ABSTRACT

The objective of this research is to establish a fundamental understanding of the relationships between the processing of thermoset matrix composite materials and the resulting mechanical behavior. A laboratory is being established to allow the fabrication of composite materials under conditions of controlled constituent treatment and fabrication. Experimental and numerical analyses are being performed to relate the processing history to the material performance. Special attention is being paid to the interplay between the microscale material behavior and the macroscale specimen performance. Detailed electron microscopy is being integrated with standard mechanical testing to provide a complete understanding of the failure process in these materials.

TITLE

High-Temperature Advanced Structural Composites

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. R. J. Diefendorf

Rensselaer Polytechnic Institute
Troy, NY 12180-3590

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Phil Parrish (202) 694-1303

SERVICE

DARPA

ABSTRACT

The DARPA High Temperature Advanced Structural Composites program has three major components:

Educational Program. A team of thirteen professors will build and add to the strong course offerings and instructional laboratories currently available at RPI. Twenty-three graduate students will be active in the program in the second and outgoing years, with support for six being provided by Rensselaer. Ten prestigious and selective "topper" financial awards are provided by Rensselaer to help attract some of the best young minds in the nation to study high temperature structural composites. Since students and faculty have diverse backgrounds, weekly "brown bag" lunches are held to force interdisciplinary interaction and enrichment for the students.

Research Program. Candidate materials systems will be selected using thermodynamic considerations and estimates of behavior from materials science theory. Selected materials will be synthesized and characterized. Also, a silicon and nitrogen containing linear polymer which can be solution or melt spun will be synthesized, and then converted to a silicon nitride fiber. Several novel matrix approaches will be studied. Nucleation of translamellar carbon whiskers followed by impregnation or CVD should allow better matrix strength. Computer characterization of pitch molecular structures, local packing, and reaction are proposed to minimize heavy expenditures in the empirical development of carbon matrices. Ceramic matrices will be developed using polymeric precursors, powder processing and pulsed CVD. Stable crack-arresting interfaces at both low and high temperatures will be developed. Three novel processing techniques will be used to fabricate intermetallic matrix composites: 1) Injection molding to give higher uniformity particularly to complex shapes; 2) Coated fine powders to provide high temperature strength that is essentially independent of the intrinsic plastic properties of the coatings, and 3) laminates produced by CVD.

The development of HiTASC will benefit from constitutive models of deformation, damage and fracture processes particularly under sustained or cyclic loading. Plastic and viscoplastic deformation will be studied using two novel approaches: 1) numerical analysis of a small volume element with the use of variational principles and 2) bimodal deformation models which recognize that fibers limit the deformation. A detailed study of the effects of large amplitude and gradient thermal histories and mechanical loading on the physical properties of composites will be conducted. Finally, crack propagation and distributed cracking will be studied in ceramic matrix composites using the concept of image cracks. Substructural damage modes will be identified by various forms of microscopy and spectroscopy. High temperature facilities will be constructed to measure fiber and matrix constituent properties as well as composite properties. Steady state, cyclic, and hot corrosion studies will be performed.

Technology Transfer. A unique national resource which would be a natural consequence of the first two components will be established. During the course of the development of HiTASC, it is likely that new important discoveries will emerge. The Center will implement procedures such that this information can be rapidly transferred to governmental laboratories and systems industries.

TITLE

Manufacture and Characterization of Silicon Carbide and Silicon Carbide Composites

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Shaik Jeelani

(205) 727-8970

Tuskegee University
School of Engineering and Architecture
Tuskegee, AL 36088

ADDITIONAL PARTICIPATING INSTITUTIONS

Collaborating with the consortium of universities led by the University of Illinois (see page 82)

SCIENTIFIC OFFICER

Dr. Alan S. Kushner

(202) 696-4305

SERVICE

ONR

ABSTRACT

The goal of this program is to develop short and continuous fiber reinforced SiC/SiC composites by the pyrolysis of fiber reinforced organosilane polymeric precursors. The effect of precursor structure on the char yield, carbon content, thermal oxidation stability, electrical conductivity, and thermal conductivity will be determined. The effects that the addition of fine ceramic powder fillers to polymer solutions used to impregnate fibers and yarns, precursor polymer structure and heating rate during pyrolysis have on defect deformation, flexural strength, interlaminar shear strength, fracture toughness, fatigue strength, electrical conductivity, and thermal conductivity will be determined.

TITLE

Fundamentals of Thin Film Studies

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Ursula Gibson

(602) 621-2539

University of Arizona
Optical Sciences Center
Tucson, AZ 85721

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Capt. Kevin J. Malloy (202) 767-4931

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - This program is addressing the shortcomings of optical films using techniques developed for ultra-high vacuum surface science and for the growth of semiconductor films as well as new understanding of the optical polishing process. APPROACH - The overall program will consist of several subcategories of work on thin films. Experimental investigations of film growth will emphasize atomic layer evaporation (ALE) of several II-VI films in an ultra-high vacuum chamber that includes in-situ diagnostics and a different approach examining ion-assisted deposition for structural modification of films. The nucleation of the films will be studied and the resulting film characterized by Rutherford backscattering (RBS) and other techniques. Theoretical approaches to modeling film growth include Monte Carlo simulations of atom-by-atom deposition with rudimentary molecular dynamics interatomic potentials, and a novel continuum description of film growth that promises analytical solutions. Mechanical properties of the film-substrate combination will be studied through the use of Brillouin scattering to determine elastic and other material characteristics. A scanning tunneling microscope/atomic force microscope will be assembled to study the initial stages of film nucleation and the overall roughness of films on an atomic scale. Finally, the polishing of glass substrates will be examined with a number of surface and subsurface optical probing techniques to determine correlations between substrate roughness and ultimate film properties.

TITLE

Center for Ultra Dynamic Performance Materials

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Siavouche Nemat-Nasser

(619) 452-4772

University of California at San Diego
Department of Applied Mechanics and Engineering Sciences
La Jolla, CA 92093

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. George Mayer

(919) 549-0641

SERVICE

ARO

ABSTRACT

The objective of the investigation is to study the response of materials to high rates of loading, impingement of energy at high densities and rates and to shock waves; to model material behavior analytically and to verify the models experimentally; to adapt and/or develop computer codes for use in design and material development; and to develop materials/material combinations to withstand damage under conditions of very high rate loading. The research program will include the following topics:

- o Microstructural characterization of materials through advanced techniques
- o Macroscopic material characterization through testing under controlled conditions
- o Micromechanics based analytical material modeling to develop constitutive relations
- o Implementation of these relations into codes
- o Experimental verification through specialized diagnostics
- o Development of new materials/material combination concepts for applications under high rate loading

TITLE

Processing and Mechanical Properties of High-Temperature, High-Performance Composites

PRINCIPAL INVESTIGATOR AND INSTITUTION

Drs. A. G. Evans and R. Mehrabian

(805) 961-4634

University of California at Santa Barbara
College of Engineering
1012 Engineering Building
Santa Barbara, CA 93106

ADDITIONAL PARTICIPATING INSTITUTIONS

Arizona State University, Stanford University, Harvard University, University of Michigan, Ohio State University, University of Wisconsin at Madison

SCIENTIFIC OFFICER

Dr. Phil Parrish (202) 694-1303

SERVICE

DARPA

ABSTRACT

This research involves a multidisciplinary, multi-institutional approach toward the solution of fundamental problems of high temperature, high performance, composites. The technical approach recognizes that the blending of a variety of diverse disciplines is essential if an understanding is to be achieved of the relationship between processing/microstructure/properties/performance of systems that contain several intrinsically different materials (such as metals and ceramics). The mechanical/structural performance of multimaterial systems can be effectively addressed by implementing a research progression that includes: materials processing and synthesis, microstructural and micro-chemical characterization, property determination, micromechanics based analysis of microstructure/property relations, and performance prediction schemes. Such research activities demand a synthesis of expertise from: metallurgy, ceramics applied mechanics, and solid state physics. A multi-institution academic consortium has been assembled to address the research problems of interest.

The research is predicated on a composites approach. Moderate knowledge exists regarding the mechanical characteristics of materials containing dispersoids, grain boundaries, etc. but there is little understanding of the properties that dictate the crack growth resistance and creep properties of more complex, reinforced materials. The major focus of the proposed research is thus on composite phenomena, wherein the deformation and fracture is dominated by the presence of a multitude of interfaces. The emphasis in metal and intermetallic matrix systems would exploit the materials selection/microstructure control pathways offered by rapid solidification. The chemistry, morphology and size of reinforcements and dispersoids would be established on the basis of their resistance to coarsening and their role in strength, fracture resistance and creep resistance. The requisite microstructures would be designed, based on the associated

micromechanics investigations. The corresponding emphasis in advanced structural ceramics would be on systems that have potential for high mechanical reliability. Compositional systems based on silicon nitride, silicon carbide and zirconia would be explored both in monolithic and composite forms. Processing research on such materials would include methods for making non-agglomerated powders and fibers from controlled precursors as well as colloidal methods of consolidating powders.

The research would be expected to provide solutions to several central mechanical problems in high temperature, high performance composites. A particular emphasis of the proposed research would be the analysis of interfacial decohesion and sliding in multimaterial systems. This analysis would be achieved by complementary studies of the mechanics of interface cracks, the characterization of interfacial zones and experimental determination of decohesion and sliding at various interfaces. The results of the decohesion/sliding study would be utilized in the prediction and interpretation of such important performance characteristics as the crack growth, creep and creep rupture of high performance composites. Damage nucleation and growth involving localized inelastic processes would also be studied by the coupled use of experimental measurements and models. Furthermore, the basic mechanical phenomena would be related to mechanical performance characteristics using micromechanics models. Initially, analytic models that relate microstructural parameters to material properties would be developed. Thereafter, as well-posed physical phenomena emerge, numerical calculations of the central effects would be performed, utilizing appropriately designed numerical algorithms.

TITLE

Liquid Crystalline Polymers

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Edward T. Samulski

(203) 486-3242 or -4698

University of Connecticut
LCP Research Center
U-136 Institute of Materials Science
Storrs, CT 06268

ADDITIONAL PARTICIPATING INSTITUTIONS

Kent State University

SCIENTIFIC OFFICER

Dr. Kay Rhyne (202) 694-1303

SERVICE

DARPA

ABSTRACT

A national center for research on liquid crystalline polymers (LCP's) is being established at the University of Connecticut's Institute of Materials Science. The LCP Research Center will investigate fundamental molecular properties of LCP's and pursue new applications of these materials. The proposed research includes studies of low molar mass liquid crystals, fluids with long-range orientational order currently utilized in electro-optic display devices, and polymers of the types used in the fabrication of ultra-high strength organic solids and nonlinear optical devices. Specific research objectives are tabulated below.

CHEMISTRY

Develop new high-temperature, high-strength polymer resins derived from cyclic hydrogen-bonded, rodlike macromolecules.

Derivatize rodlike LCP's in order to improve polymer-polymer compatibility in blends.

Synthesize low glass transition temperature, ordered phases at interfaces based on siloxane polymers. (KSU)*

PHYSICS

Study macromolecular melt dynamics by nuclear magnetic resonance (NMR) constructing a framework for contrasting the dynamics and fluid structures exhibited by LCP's with the behavior of conventional melts of flexible polymers.

Characterize at the monomer level the response of polymers to external forces using NMR.

Develop procedures for getting quantitative structural data from LCP's with x-ray diffraction methods.

Investigate the effect of pressure on LCP's and potential LCP's i.e., to study the feasibility of using pressure to drive conventional polymer melts into liquid crystalline phases.

Measure basic physical properties (elastic and viscosity coefficients, heat capacities, orientational order, and intrinsic nonlinear optical response) of extant LCP's. (KSU)

ENGINEERING

Examine alloys of LCP's with conventional polymers in terms of their behavior as reinforced polymer composites.

Prepare ultra-low density microcellular structures from lyotropic LCP's.

Study ionic LCP's as materials for potential low-dimensional conductors and large aperture optical devices.

Characterize the miscibility of low molar mass liquid crystals with conventional polymers.

Evaluate low molar mass liquid crystals in sub-micron dispersions in conventional polymers for fabricating large area electro-optic devices. (KSU)

*Subcontracted research to Kent State University (KSU)

TITLE

Structural and Electrically Conductive Polymers: Synthesis, Measurement, and Theory

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. K. B. Wagener

(904) 392-4666

University of Florida
Department of Chemistry
Gainesville, FL 32611

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Kay Rhyne (202) 694-1303

SERVICE

DARPA

ABSTRACT

A comprehensive program for the synthesis and study of electrically conductive and structural polymers is proposed. One approach will involve step-polymerization chemistry to make planar polymers incorporating high-aspect-ratio repeat units, in which the polymer will consist of conjugated chains which include pi-bonded heteroaromatic rings. The rings may either be part of the polymer backbone or be attached as side groups to the chain, and their high aspect ratio is expected to force a stacking morphology, leading to high crystallinity, resistance to degradation, and good contact among the polymer chains. An alternate synthetic approach will involve chain polymerization chemistry to create conductive block copolymers having multiphase morphologies as well as monodisperse conductive polymers. Calculations of the electronic structure of these materials will be performed within a semiempirical LCAO method. In addition, a first-principles calculation for a model substituted polyene based on the coupled-cluster method in Fock space will be carried out. This method enables electron-electron correlations to be included in a realistic way in calculations of electronic structure. The electrical conductivity, microwave conductivity, infrared properties, and optical properties of these polymers will be measured, enabling the determination of the frequency-dependent conductivity and dielectric function. These quantities can be related to the mechanisms for charge transport in the material, to the vibrational spectrum, to the energy band gaps, and to the electronic bandwidth. X-ray scattering measurements will be made to determine the structures of the materials, and to characterize short range order and possible phase transitions. Finally, the mechanical performance of these polymers will be determined.

Materials resulting from this research could include electronically tailored planarizing polymers for layered microelectronic structures. The ultimate goal of this work is to create polymers which do not require chemical oxidation or reduction to exhibit a high degree of conductivity.

Another important result of this research will be the multidisciplinary training of graduate students and postdoctoral associates in the field of polymer science, wherein the disciplines of chemistry, physics and materials science will be represented. A total of 25 Navy/DARPA Pre- and Postdoctoral Fellows will be involved in this effort during the five-year period.

TITLE

Cement Composite Materials

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. J. Francis Young

(217) 333-6960

University of Illinois
Department of Civil Engineering
Champaign, IL 61820

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Maj. Joseph W. Hager (202) 767-4933

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - The objective of this effort is to establish a body of university researchers who will conduct fundamental interdisciplinary investigations of both the chemistry and microstructure/mechanical property relationships of cementitious materials and fiber reinforced cementitious composites. APPROACH - There are four major areas under investigation. The first area, High Performance Cement Matrices, focusses on the principles which provide strengthening to the macro-defect free (MDF) and DSP (Densified with Small Particles) cement systems. These investigations attempt to discover how the mechanical properties of low porosity cement matrices can be optimized through control of composition and microstructure. Since the major strengthening phases of these systems are either calcium silicate hydrate or hydrated calcium aluminate, research will be conducted on how the microstructure of pastes containing these phases determines the mechanical properties and the long-term durability of the material, so that intelligent manipulation of microstructure can be achieved. Research area #2 considers fiber-reinforced cement matrices. This area will concentrate initially on reinforcing DSP and MDF materials, but will incorporate other cement matrices as they become developed. The interfacial zone between fiber and matrix will be thoroughly characterized, and various strategies will be pursued to modify fiber-matrix bond strength to determine the effects on mechanical properties. In research area #3, Novel Cement Matrices, two major thrusts will be conducted: 1) the investigation of potential new cementitious matrices based on new chemistries to create inorganic polymers and 2) the creation of new organic-inorganic composites at the molecular level. Emphasis will be placed on the formation of block copolymers with both organic and inorganic components. Research area #4 will focus on cements with controlled microstructures. This is somewhat akin to area #2 except that the second phases will be extended beyond fibers to include second phase fillers and second phases formed in situ.

TITLE

Center for Advanced Construction Technology

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Joseph P. Murtha

(217) 333-6937

University of Illinois at Urbana-Champaign
Department of Civil Engineering
Urbana, IL 61801

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Gary Anderson

(919) 549-0641

SERVICE

ARO

ABSTRACT

The research program of the Center is directed toward two main objectives: to achieve significant life-cycle cost savings for military construction, and to develop battlefield structures which are affordable, constructible, maintainable, and survivable in extreme environments. The research program includes:

- o Construction materials and lightweight structures;
- o Non-destructive test and evaluation techniques for construction;
- o Explosion effects: blast, shock, EMP;
- o Computer-based systems for planning, design, construction, maintenance, and renovation;
- o Special technologies for constructed works.

The Center will develop a multi-disciplinary research program involving the departments of civil, mechanical, electrical, ceramic, and general engineering; computer science, physics, metallurgy, theoretical and applied mechanics, and architecture. The research will be conducted by regular and visiting faculty, post-doctoral fellows, and graduate students. The Center will increase University-Army laboratory cooperation and provide advanced education for future Army construction needs. As a research by-product, available research equipment will be modernized.

TITLE

Center for Advanced Composite Materials Research

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Su Su Wang

(217) 333-1835

University of Illinois at Urbana-Champaign
Department of Theoretical and Applied Mechanics
Urbana, IL 61801

ADDITIONAL PARTICIPATING INSTITUTIONS

Drexel University, University of Maryland, Michigan State University,
Virginia Polytechnic Institute and State University

SCIENTIFIC OFFICER

Dr. Alan S. Kushner (202) 696-4305

SERVICE

ONR

ABSTRACT

The objectives of the Center are: (1) to conduct basic research on critical chemistry, materials science, mechanics, and structures problems currently confronting the Navy and to be encountered in its use of advanced structural composite materials, (2) to promote collaboration, interaction, and technology transfer with scientists and engineers in Navy and other DoD laboratories and industry, (3) to increase the number and quality of graduate students involved in the study of composite materials, and (4) to enhance the quality of laboratory facilities for students and faculty involved in composite materials research at the universities in the Center.

As a focal point of the Center's research, the initial thrust of the research focuses on the basic science and engineering of third-section composite materials and structures. The following research thrusts are being addressed:

1. Chemistry and physics of composite matrix materials,
2. Composite interface/interphase thermodynamics, kinetics, and mechanics,
3. Effects of processing variables, microstructural modification, and control,
4. Microstructure, defect and damage characterization, and associated NDE,
5. Micromechanisms and micromechanics of deformation and failure, and composite constitutive equations,
6. Mechanics and failure of thick-section composite laminates,
7. Composite structural mechanics analysis, testing, and design optimization,
8. Computational mechanics and methods,
9. Damage tolerance and fracture,
10. Durability, fatigue life prediction, and environmental effects.

TITLE

Advanced Electrical and Structural Polymers

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Frank E. Karasz

(413) 545-0433

University of Massachusetts (Jointly funded by AFOSR and DARPA)
Department of Polymer Science and Engineering
Amherst, MA 01003

ADDITIONAL PARTICIPATING INSTITUTIONS

Wright State University

SCIENTIFIC OFFICER

Dr. Kay Rhyne (202) 694-1303

Dr. Donald R. Ulrich (202) 767-4963

SERVICE

DARPA

AFOSR

ABSTRACT

The research planned encompasses five sub-sections. These include work in (a) Electrical/magnetic properties of polymers. New polymers will be synthesized and ultrastructures will be obtained which will lead to the development of viable new materials for ultra-fast polymer-based electronic devices and for light weight conductors. (b) Nonlinear optical properties. New synthetic approaches are planned for creating macromolecular structures which are expected to have nonlinear optical properties. (c) Advanced ultra structural polymers. Research is planned in several high temperature polymer systems based on blends, alloys and composites. A new understanding of the relationship of phase behavior and phase separation in macromolecular blends will be used as the foundation of research which is expected to result in light-weight, high strength, materials for use in harsh environments. (d) Novel architecture and characterization. Investigations will be focused on block copolymers, on surface modified polymers and on new characterization techniques for acquiring a detailed understanding of the nature of these related materials at the molecular level and thereby furthering the ability to predict and design specific properties based on the molecular structure of the polymer systems. (e) Processing. In the concomitant polymer processing research program the versatility of the materials produced in other phases of the planned Center program with respect to processing methodologies will be studied. This includes investigations into gelation, into processing of semi-intractable polymers by blending and into the application of artificial intelligence computer science and technology to produce macromolecular components with greater control and with optimally defined properties.

TITLE

Polymers by Non-Redox Processes: Synthesis, Physical Studies and Application

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Alan G. MacDiarmid

(215) 898-8307 or -4786

University of Pennsylvania
Department of Chemistry
Philadelphia, PA 19104-6323

ADDITIONAL PARTICIPATING INSTITUTIONS

Ohio State University, Massachusetts Institute of Technology, University of Rhode Island, Montclair College

SCIENTIFIC OFFICER

Dr. Kay Rhyne (202) 694-1303

SERVICE

DARPA

ABSTRACT

The contract involves: (i) Research on conducting polymers with particular emphasis on those organic polymers whose conductivity can be raised to the metallic regime by non-redox doping processes, (ii) the training of U.S. citizens especially in academic laboratories in the experimental and theoretical aspects of conducting polymers and (iii) the immediate dissemination of research results to personnel at D.O.D. laboratories by means of specially arranged meetings and workshops.

The above broad objectives will be accomplished by means of funding to the School of Arts and Sciences and to the School of Engineering at the University of Pennsylvania, and by sub-contracts to the Department of Physics and the Department of Chemistry (The Ohio State University), the Materials Science Department (Massachusetts Institute of Technology), Department of Chemistry (University of Rhode Island), Department of Chemistry (Montclair College, N.J.) and to Lockheed Corporation (Cf).

Specific tasks are as follows: (1) The chemical and electrochemical synthesis of a broad new class of organic polymers which can be "doped" to the metallic regime by processes which involve no change in the number of electrons associated with the polymer backbone. (2) Attempted synthesis of a new class of organic polymers which are intrinsically metallic without doping. (3) A detailed study of the conditions and mechanisms involved in the electrochemical syntheses. (4) Complete characterization of the new polymers both in their undoped and doped forms by standard procedures such as elemental analysis, infrared, ultraviolet, N.M.R. spectroscopy, molecular weight, conductivity, cyclic voltammetry, stability to heat, air and water under a variety of conditions, etc. (5) Detailed studies of the magnetic properties, thermoelectric power, photoconductivity, optical and photo-induced optical properties, dependency of conductivity on temperature, electric field, magnetic field and frequency, all of which will provide critically important information concerning the electronic structure, doping

and conduction mechanism, linear and non-linear phenomena and roles played by solitons, polarons and bipolarons in these anisotropic systems. (6) Use of the data obtained in (1) to (5) above to design conducting polymers exhibiting preselected desirable electronic, optical, magnetic, thermal, chemical and mechanical properties. (7) Modifying, where necessary, the properties of those materials of greatest interest to D.O.D. to meet specific requirements for a given end use.

TITLE

Electronic and Ionic Transport in Polymers

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. John R. Reynolds

(817) 273-3811

University of Texas at Arlington
Department of Chemistry
Arlington, TX 76019

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Kay Rhyne (202) 694-1303

SERVICE

DARPA

ABSTRACT

A detailed interdisciplinary program covering the synthesis and complete chemical, physical, electronic and surface characterization of a series of advanced polymer materials capable of charge transport will be carried out. This research effort is directed into the materials areas of electronically conducting polyheterocycles, poly(organophosphazene) solid electrolytes containing phosphazene linkages, liquid crystalline polymeric conductors based on phenylene-vinylene and quinonyl-vinylene mesogenic units and polarizable dielectric copolymers of vinylidene fluoride. These systems address some of the major needs of polymeric materials required in advanced electrical applications which include charge storage (batteries and capacitors), charge transport (electronic and ionic), processability (solution and liquid crystalline), microwave absorption, and thermal stability.

The research approach involves the synthesis of new materials with specific macromolecular structures for desired properties. Materials characterization techniques include electrochemistry, spectroelectrochemistry, reflectance Fourier transform infrared spectroscopy, solids nuclear magnetic resonance spectroscopy, electron paramagnetic resonance spectroscopy, theoretical modeling, fluorescence, thermal analysis, surface analysis, electrical conductivity, and microscopy.

TITLE

Nonlinear Response to Rapid Energy Deposition

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Y. Gupta

(509) 335-7217

Washington State University
Department of Physics
Pullman, WA 99164-2814

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Spencer Wu (202) 767-4935

SERVICE

AFOSR

ABSTRACT

Description: The objective of this study is to focus on the investigation of two basic problems relating non-linear response of materials subjected to rapid energy deposition. One involves the research of identification of the mechanisms responsible for inelastic deformation of brittle materials subjected to shock wave type loads. The other involves research study that examines the detailed micro-mechanisms responsible for energy release of di-electric materials subjected to an intense laser radiation. The macroscopic mechanical and thermodynamic responses of the material to the macroscopic modifications will also be investigated in this study.

G. FLUID DYNAMIC SYSTEMS

Services' Areas of Emphasis:

Hydrodynamics (ONR)

Unsteady and Separated Flows (AFOSR)

Turbulent Flow in Fluid Dynamic Systems (DARPA)

TITLE

Turbulent Flow in Fluid Dynamics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Lawrence Sirovich

(401) 863-3720

Brown University
Division of Applied Mathematics
Providence, RI 02912

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Helena S. Wisniewski (202) 694-5800

SERVICE

DARPA

ABSTRACT

OVERVIEW: The goal of this effort is to develop techniques for the analysis, prediction and control of turbulent flows through the integration of mathematical methodologies, computers and experiments. To achieve this goal Brown will accomplish the following objectives: the improvement of design capabilities for aircraft and hypersonic jet engines; the improvement of combustion efficiencies; the development of new mathematical methodologies and techniques for describing turbulent flow and the transition to turbulence, and for data reduction to be used in the simulation of fluid flows. The methodologies that will be employed to achieve these objectives include: developing mathematical methodologies for the application of eigenfunction methods, for the refinement of eigenfunction methods using inertial manifolds, for the characterization of vorticity using fractal dimension, for data reduction using attractor sets, for the application of spectral methods; performing experiments on open flows to obtain the degree of turbulence by using their new 3-d probe to measure vorticity and to measure the fractal dimension between turbulent and non-turbulent regions by verifying mathematical models of chaos. Anticipated payoffs include: improved capabilities for aircraft design and ram jet engine design for hypersonic speed; drag control techniques; characterization of surface and subsurface wakes; and improved combustion efficiencies as well as stability control. Although each of the three universities under this URI (Brown, Princeton and UCSD) have been awarded separate contracts they will be collaborating with each other on the research projects.

TITLE

Unsteady and Separated Flows

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Anatole Roshko

(818) 356-4486

California Institute of Technology
Department of Aeronautics
Pasadena, CA 91125

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Jim Wilson (202) 767-4935

SERVICE

AFOSR

ABSTRACT

Description: Experimental studies will be conducted of globally steady and unsteady separated flows on lifting wings. Water and wind tunnel facilities will be used to explore the effects of planform and control flaps or spoilers for arbitrary motions (including varying incidence while traveling a curved trajectory) of sharp edged models. Qualitative and quantitative flow field data will be obtained, as well as force and loading data. The effects of adaptive feedback control techniques on the dynamics of separated turbulent shear layers will be explored in water tunnel experiments. The computer controlled experiments will be designed to handle a large number of concurrent tasks. Vortex methods will be used to simulate numerically the dynamics of large scale separated vortices, to determine the influence of transient motions of the body on these dynamics, and to explore control strategies that produce desired effects.

TITLE

Unsteady and Turbulent Flows

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Hassan Nagib

(312) 567-3213

Illinois Institute of Technology
Department of Mechanical and Aerospace Engineering
10 W. 32nd Street
Chicago, IL 60616

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Jim McMichael (202) 767-4936

SERVICE

AFOSR

ABSTRACT

Description: A unique national facility for basic research in transitional, turbulent, and unsteady flows at realistic flight Reynolds numbers has been established at IIT. Transition to turbulence in boundary layer flows subjected to controlled spanwise disturbances will be studied experimentally. Evolution of disturbances through the late stages of transition will be followed to explore the link between transitional and turbulent flow structures. The dynamics of organized structures in turbulent boundary layers with and without control will be investigated at realistic flight Reynolds numbers in the unique National Diagnostic Facility. Techniques will be developed for reactive feedback control of unsteady and separated flows. New flow diagnostics using laser scanning and other sophisticated techniques will also be developed.

TITLE

Turbulent Flow in Fluid Dynamics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Steven A. Orszag

(609) 452-6206

Princeton University
Department of Applied and Computational Mathematics
218 Fine Hall
Princeton, NJ 08544

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Helena S. Wisniewski (202) 694-5800

SERVICE

DARPA

ABSTRACT

OVERVIEW: The goal of this effort is to address modern problems of complex transitional and turbulent flows by integrating mathematical methodologies, computer simulations, and experiments. To achieve this goal Princeton will accomplish the following objectives: improving aircraft design capabilities by developing the capability to predict and calculate 3-D flow past an entire aircraft through different flight regimes; developing mathematical models for spatial temporal chaos and fully developed turbulence, for resonant nonlinear instability for high speed jets, for the foundations of cellular automata, and for the long time stability and behavior of discrete vortex approximations; developing new robust, efficient algorithms for the accurate solution of Navier-Stokes equations on modern supercomputers and the analysis of flows through user interactive high resolution 3-D graphics; and performing experiments on closed flows to access the role of chaotic theory in describing hydrodynamic flows. The methodologies that will be employed to achieve these objectives include: developing the necessary mathematical methodologies for tetrahedrization techniques, for the development and application of spectral methods, and for the development of advanced subgrid turbulence models based on renormalization group methods and multigrid and adaptive grid methods; performing experiments on closed flows to verify models of turbulence and chaos, to study time dependent patterns, chaotic phenomena and transport in hydrodynamic flows, to understand turbulent bursts, and to study modal interactions in surface waves and transport in unstable flows. Anticipated payoffs include: innovations in engineering design for aircraft and military vehicles; drag control techniques; software/hardware to be used as engineering tools; algorithms for accurate solution of Navier-Stokes equations; and a Navier-Stokes desk top computer. Although each of the three universities under this URI (Brown, Princeton and UCSD) have been awarded separate contracts they will be collaborating with each other on the research projects.

TITLE

Flow Control

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Bill Reynolds

Stanford University
Department of Mechanical Engineering
Stanford, CA 94305-6060

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Jim Wilson (202) 767-4935

SERVICE

AFOSR

ABSTRACT

Description: Interdisciplinary investigations, combining experts in fluid dynamics and automatic control theory, will be conducted on vortex interaction in free jet flows, the mechanics of boundary layer separation control by streamwise vortices, and control of vorticity in the separated flow field above a delta wing. The research tasks to be accomplished include identification of alternative flow states; understanding the mechanisms that produce and sustain these states; determination of the minimum information needed for sensing the flow states; and development of suitable actuators and feedback control algorithms.

TITLE

Turbulent Flow in Fluid Dynamics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Henry Abarbanel

(619) 534-5590

University of California at San Diego
Institute for Nonlinear Science, B-003
La Jolla, CA 92093

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Helena S. Wisniewski

(202) 694-5800

SERVICE

DARPA

ABSTRACT

OVERVIEW: The goal of this effort is to manage and predict turbulent flow through an experimental, mathematical and computational attack on the fundamental scientific aspects of the transition to turbulence. The result will be a firm quantitative foundation for the practical application of the control of fluid transitions. To achieve this goal UCSD will accomplish the following objectives: developing mathematical models of turbulent flows, of the transitions from laminar to turbulent flow in open systems, of the movement of vehicles in a fluid, and of the flow of fluid across natural topography; understanding and describing the transition to turbulence in open flows; and producing innovative numerical and computational tools for the simulation and analysis of fluid flows. The methodologies that will be employed to achieve these objectives include: developing mathematical models of turbulent and chaotic flow; verifying mathematical models through experiments; performing laboratory experiments on open flows for assessing stratified flows and objects in the flow, the dynamics of interfaces between turbulence and laminar flow, and vortex shedding; inter-facing experimental findings with computer simulations by using their new automated particle tracing method, and using fractal dimension to characterize turbulence. Anticipated payoffs include: drag control on aerodynamic and hydrodynamic bodies; defense utilization of coastal nonlinear instabilities; enhanced combustion efficiencies; improved interpretation of oceanic surface signatures; and the characterization of surface and sub-surface wakes in turbulent media. Although each of the three universities under this URI (Brown, Princeton and UCSD) have been awarded separate contracts they will be collaborating with each other on the research projects.

TITLE

Program for Ship Hydrodynamics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Robert Beck

(313) 764-0282

University of Michigan
Department of Naval Architecture and Marine Engineering
Ann Arbor, MI 48109

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Michael M. Reischman (202) 696-4406

SERVICE

ONR

ABSTRACT

The program for Ship Hydrodynamics at the University of Michigan addresses a problem of acute Navy interest: the hydrodynamic aspects of the remote sensing (acoustic and non-acoustic) of ships. The five year effort will seek to improve fundamental understanding by undertaking a number of interrelated research problems.

Much is still unknown and there is a lack of consensus concerning the physics to the remote sensing of ship wakes by Synthetic Aperture Radar (SAR). Therefore a major task of the program is to obtain fundamental experimental data on radar signatures of wakes in the Michigan towing tank (the largest university towing tank in the U.S.). Calibrated radar scatterometers will be mounted over the tank and the return signal correlated with high resolution fluid surface measurements in order to determine the physical mechanisms. The instruments to make these highly accurate measurements will be unique in the world. They will be designed and built by the University's Space Physics Research Laboratory and the Environmental Research Institute of Michigan (ERIM). Since some of the instrumentation utilizes thermal images, the infrared sensing of ship wakes will be investigated at the same time. The system will be portable and applicable to full scale as well as model studies.

The fluid flow on the surface of the wake is a manifestation of the flow below the surface. The flow in the wake is extremely complex, being a combination of turbulent shear flows, coherent vortex flows, free surface waves, internal waves, and bubble flows. There are also complex interactions among the various components. Analytical, numerical, and experimental investigations of these flows and their interactions are being undertaken.

The flow in the wake is a direct result of the fluid dynamic processes that occur close to the body. Several of the research projects thus involve the flow on the body and in the near wake region. These projects include: turbulent flow in both the boundary layer and wake, transition flow, viscous generation and diffusion of vorticity, separated flows, nonlinear ship waves, and bubble flows in the boundary layer.

A multidisciplinary team of faculty members from six academic departments and ERIM personnel are conducting the research. In addition eight graduate fellowships and 16 research assistantships are supported by the research program. The program is closely coordinated with related research at NRL and DTNSRDC and will feed information to ONCR's Exploratory Development Program on Remote Sensing of Ship Wakes.

TITLE

Dynamics and Control of Turbulent Shear Flows

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Richard E. Kaplan

(213) 743-6593

University of Southern California
Department of Aerospace Engineering
Los Angeles, CA 90089-0192

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Micheal M. Reischman

(202) 696-4406

SERVICE

ONR

ABSTRACT

This program combines theory and measurements to: analytically examine turbulent flows by using novel methods of nonlinear dynamics; and experiment on ways of actively controlling turbulence. The realization of these related goals will be a significant impact on hydrodynamic, propulsive, and acoustic naval systems.

Recent progress in the description of the dynamics of nonlinear systems reveals that the behavior of these systems appears as chaotic and random. However, this behavior is governed explicitly by known and deterministic equations. Because these systems are relatively simple, and because turbulence is chaotic, there is potentially a great opportunity to develop understanding of complex turbulent flows from relatively simple equations. The research focuses on analyzing bounded and free turbulent shear layers, which play a dominant role in turbulent flows. The analysis uses nonlinear evolution equations which, once numerically solved, can elucidate possible mechanisms for control of the shear layer.

Concurrently with the theory, several experiments aim at providing physical understanding and methods of active control of turbulence. The three-dimensional evolution of free and confined shear layers are being measured under the influence of different temporal and spatial inputs such as acoustical perturbations. Thus, a variety of possible control mechanisms are being investigated. Novel methods for control of wall bounded shear layers are being examined by using unsteady suction mechanisms of instability, and transition from laminar to turbulent flow is being measured in shear layers with density stratification.

Potential applications include active control of turbulent flow around naval vehicles and weapons systems, including systems that are used for propulsion and acoustic control. The research on stratified flows may impact detection methods of submerged vehicles and the understanding of ocean physics.

H. HUMAN PERFORMANCE FACTORS

Services' Areas of Emphasis:

**Cognitive, Perceptual, and Neural Bases of Skilled
Performance (AFOSR)**

TITLE

The Cognitive, Perceptual, and Neural Bases of Skilled Performance

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Stephen Grossberg

(617) 353-7857

Boston University
Center for Adaptive Systems
Boston, MA 02215

ADDITIONAL PARTICIPATING INSTITUTIONS

Brandeis University, Harvard University, Massachusetts Institute of Technology,
Northeastern University

SCIENTIFIC OFFICER

Dr. John F. Tangney (202) 767-5021

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - This contract would establish a Boston-area consortium, called the Boston Consortium for Adaptive Systems, to carry out advanced research and training in the areas of cognitive processing, auditory and visual information processing, and the neural bases of learning and behavior. The Boston-area universities and laboratories participating in the Consortium are Boston University, Brandeis University, Harvard University, M.I.T., Northeastern University, the Retina Foundation, and The Rowland Institute for Science.

APPROACH-The Consortium would carry out a multi-faceted program of individual and collaborative modeling, laboratory development, experimentation, hardware development, teaching and organization of interdisciplinary scientific meetings and seminars. Research areas include: development of a unified neural model of 3-D form perception (boundary, texture, stereo, surface, motion, color, brightness perception); psychophysical experiments on surface, color, and texture perception; hardware development of multi-scale oriented filters for 3-D image analysis and of massively parallel neural pattern recognition devices; neural modeling of stable self-organization of cognitive recognition codes, including mechanisms of unitization, attention, parallel search, and hypothesis testing; experiments and modeling of speech and visual object recognition; experiments and real-time neural modeling of skilled arm movements and eye-arm coordination; experiments and real-time neural modeling of animal conditioning, notably factors controlling attention, reinforcement, timing, and execution of learned movements.

TITLE

Institute for the Study of Human Capabilities

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Charles S. Watson

(812) 355-4156

Indiana University
Speech and Hearing Sciences
Bloomington, IN 47405

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. John F. Tangney

(202) 767-5021

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - The goal of the Institute, which will be established at Indiana University, will be to bring together a group of eight primary co-investigators and several associate investigators to focus on problems of skilled human performance. These investigators have expertise in the areas of sensory processes including vision, audition, and touch, and in the areas of human cognition and decision making. Expertise in human factors will be enhanced by the acquisition of a resident senior scientist in the field of human factor/human engineering and by arranging for visits by other human factors specialists. These specialists will conduct seminars and workshops on human factors problems and will benefit from exposure to ongoing research in the Institute. APPROACH - Specific projects will examine the abilities of human subjects to use information obtained from visual, auditory, and tactual displays. Both empirical and theoretical studies are planned. The studies of human cognition will include projects on machine-aided detection and recognition, the integration of information from multiple observations, the automatization of decision making, and automatization as a way of overcoming attentional limitation. In hearing, studies will include measures of the auditory system's dynamic range, the use of multiple invariant cues in recognition of acoustic signals, pattern discrimination abilities, optimal "packing" of information in auditory patterns and discriminability of noise samples. In addition, the development of a general model for complex pattern discrimination is proposed. In vision, projects will include both theoretical and experimental studies of human color vision, including response of subjects to color video patterns. Additional studies will examine peripheral vision and the identification of moving stimuli. Studies of the tactual sense will include the development of a new tactual stimulator, measures of temporal masking and attention, and the study of higher order processes. The Institute will be available as a technical resource center for the military and private sectors in solving applied problems related to human information processing and skilled performance.

TITLE

Cognitive, Perceptual and Neural Bases of Skilled Performance

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Lloyd Kaufman

(212) 598-7763

New York University
Department of Psychology
6 Washington Place
New York, NY 10003

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Alfred R. Fregly

(202) 767-5021

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - A Center of Excellence will be established at New York University in the area of cognitive, perceptual and neural bases of skilled performance. The program is composed of three facets. These are: a core research program to be conducted under the supervision of eight co-principal investigators; training of students and post-doctoral fellows and interns from DoD laboratories by the investigators and by other NYU faculty; a formalized procedure for interacting with other DoD laboratories. This interaction will take the form of collaborative research, consulting, and colloquia given by investigators at DoD facilities. An overriding consideration in designing this program is that it attempt to achieve collaboration among many highly regarded research scientists and to develop tighter theoretical linkages among the diverse areas of research that are addressed. APPROACH - The core research program will emphasize cognitive studies in the areas of human memory for concrete and abstract words, picture recognition, intelligibility vs auditory memory for auditory messages, and the dimensional structural of knowledge spaces. In addition to classic psychological methods, measures of brain activity will be employed to test theories of processes underlying some of these cognitive functions. The program also includes work on sensory psychophysics and physiology, particularly in color vision and in motion perception. Single unit recording will be employed, as well as standard psychophysical procedures. Some neuromagnetic recording will be done for the first time in the area of color vision. The aim of the latter is to search for brain areas specially concerned with processing chromatic information.

TITLE

Center for the Study of Rhythmic Processes

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Nancy Kopell

(617) 437-2450

Northeastern University
Department of Mathematics
Boston, MA 02115

ADDITIONAL PARTICIPATING INSTITUTIONS

Brandeis University, Cornell University, University of Pittsburgh

SCIENTIFIC OFFICER

Dr. Alfred R. Fregly (202) 767-5021

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - A Center for the Study of Rhythmic Processes (CSRP) will be established. Rhythmic processes are ubiquitous in biology, but much remains to be understood concerning the generation of these processes and the control of rhythmic activities. Since these processes involve the interaction of large numbers of coupled oscillators, such understanding requires the close collaboration of physiologists and mathematicians. CSRP will facilitate such collaborations and promote interdisciplinary training and exchange. Its activities will include active research programs using mathematical and physiological techniques, as well as workshops and seminars. Dr. Kopell will direct and coordinate CSRP functions from her home institution. Research will be done collaboratively among the participating groups. APPROACH - Drs. Kopell and Ermentrout will continue to develop a general mathematical treatment of populations of oscillators, a treatment designed to interpret available and potentially available data. This theory is qualitative, deducing qualitative, but detailed conclusions from robust qualitative data. The theory will be guided by experiments from several model systems. One of these systems, studied by Dr. Marder, is the crustacean stomatogastric ganglion, one of the best understood neuronal networks that generates complex rhythmic output. Questions concerning the control of frequency and phase relationships between parts of this network will be studied. Comparisons between the activity of such an isolated network and one functioning in the behaving animal will be explored. Drs. Marder and Cohen will investigate the detailed mechanisms by which oscillatory circuits in the stomatogastric ganglion are coupled to those in other ganglia. Another physiological system, studied by Dr. Cohen, is the lamprey spinal cord, an ideal vertebrate preparation for the analysis of collections of "unit" oscillators. It is expected that the mathematics will give further insight into the nature of the coupling, and in particular to the successful reconstruction of that coupling following spinal transection. Dr. Cohen will also explore the detailed structure of the lamprey oscillators.

I. ENVIRONMENTAL SCIENCE AND TECHNOLOGY

Services' Areas of Emphasis:

Geosciences (ARO)

Ocean Remote Sensing and Modeling (ONR)

Oceanography (ONR)

Ocean Engineering (ONR)

Arctic Science and Technology (ONR)

Stimulated Auroral Ionosphere Research (ONR)

Theory and Analysis of the Geo-Plasma Environment (AFOSR)

Surface Reactions in the Space Environment (AFOSR)

Solar Activity and Variability (AFOSR)

TITLE

Center for Geosciences

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Thomas H. Vonder Haar

(303) 491-8448

Colorado State University
Department of Electrical Engineering
Fort Collins, CO 80523

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Walter D. Bach

(919) 549-0641

SERVICE

ARO

ABSTRACT

The Center for Geosciences Research at Colorado State University has the objective of enhancing the Army's technology base in the atmospheric and terrestrial sciences. The University Research Initiative (URI) program will have three principal spheres of basic research investigation - meteorological, hydrological, and geomorphological processes - focusing on their effects near battlefield scales. These basic processes are investigated by developing and using research models in conjunction with remote and in situ field observations. The research is complemented by active interaction of the investigators working on data from the same events. A central concept of the Center is the study of information extraction techniques and integration of data from different sources into a cohesive, consistent framework. Facilities are provided for Army scientists to have university research visits and for university personnel to bring the basic research to Army laboratories. Conferences and workshops on the Center's research topics will be held as appropriate.

TITLE

Arctic Ice-Ocean Dynamics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. William Hibler, III

(603) 646-2888

Dartmouth College
Thayer School of Engineering
Hanover, NH 03755

ADDITIONAL PARTICIPATING INSTITUTIONS

University of Colorado

SCIENTIFIC OFFICER

CDR Thomas S. Nelson (202) 696-4395

SERVICE

ONR

ABSTRACT

The purpose of this program is to better understand and model dynamics/mechanics of the Arctic ice-ocean system. This effort capitalizes on accumulated multidisciplinary experience of three highly regarded Principal Investigators: Drs. Hibler and Schulson, Dartmouth College, and Dr. Barry, University of Colorado, are recognized authorities with a combined total of over 60 years of experience in Polar related problems. Facilities at both institutions are especially suited for this research.

The thrust of this research will address fundamental questions of ice rheology by coupling large scale ice/ocean/atmosphere forcing with microscale fracture mechanics. Numerical modeling and laboratory experiments conducted at Dartmouth and detailed analyses of existing data prepared by the University of Colorado will integrate mesoscale phenomena with microscale physical events. This effort will integrate processed data from in situ and remote sensors (satellite) into second generation predictive Arctic environmental and acoustic models. Capitalizing on National Laboratory (NCAR and CRREL) facilities adjacent to both participating institutions, this initiative establishes Dartmouth College as a center of excellence addressing Navy related Arctic problems.

TITLE

Center for Applied Solar Physics

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. David M. Rust

(301) 953-5414

Johns Hopkins University
Space Department
Applied Physics Laboratory
Johns Hopkins Road
Laurel, MD 20707

ADDITIONAL PARTICIPATING INSTITUTIONS

University of California at San Diego

SCIENTIFIC OFFICER

Dr. Henry R. Radoski

(202) 767-4906

SERVICE

AFOSR

ABSTRACT

The Johns Hopkins Applied Physics Laboratory, in collaboration with the University of California at San Diego, is improving solar activity observations and prediction techniques through a three-year interdisciplinary program of instrumentation development and fundamental research on solar magnetic fields. Design and fabrication of a full vector magnetograph, with 0.5 arcsecond resolution, is the keystone of the program. The instrument is based on ultra-narrow pass-band tunable filter technology recently developed at the Johns Hopkins Applied Physics Laboratory. A substantial extension of the filter program will be accomplished, in order to modify other new optical devices, such as high-speed liquid-crystal and tunable acousto-optical filters, for the requirements of vector magnetography. The goal of eventually operating a magnetograph in space has a strong influence on the magnetograph design.

TITLE

Center in Theoretical Plasma Research

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Tom T. S. Chang

(617) 253-7523

Massachusetts Institute of Technology
Center for Space Research
77 Massachusetts Ave.
Cambridge, MA 02139

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Lt. Col. James P. Koerner (202) 767-4960

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - Develop methods for specifying and predicting the onset of ionospheric irregularities. Investigate the phenomena of ionospheric-magnetospheric coupling. Study the nonclassical polar wind, suprathermal particle distributions, and subvisual polar cap arcs. Assess the effect of these and other phenomena on the performance of Air Force systems.

APPROACH - Investigate the phenomena of ionosphere-magnetosphere coupling. Study the energization processes of ions in the topside ionosphere. Investigate the phenomenon of high latitude F-region plasma turbulence. Study the nonclassical polar wind, suprathermal polar cap particle distributions, and subvisual F-region polar cap arcs. Investigate the phenomenon of counterstreaming electrons in the supra-auroral region. Study the effects of strong plasma turbulence in the magnetosphere and ionosphere, including ion holes and turbulent magnetic reconnection.

TITLE

Center for Surface Radiation Damage Studies

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Laurence D. Marks

(312) 491-3996

Northwestern University
Department of Material Science and Engineering
The Technological Institute
Evanston, IL 60201-9990

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Lt. Col. Larry W. Burggraf (202) 767-4960

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - The objective of this research is to understand interactions of energetic electrons and photons with aerospace materials (including optical materials, polymers and semiconductors) leading to damage of surfaces and near-surface layers. Mechanisms of material damage at surfaces due to electron interactions, including desorption induced by electronic transitions (DIET), radiation induced surface reactions and damage to semiconductors, will be studied using the high-resolution electron microscope.

APPROACH - The research team will employ an ultra-high vacuum high-resolution electron microscope coupled with surface spectroscopy techniques to study threshold defect formation and damage in optical materials, electronic materials, and polymers produced by energetic electrons and short-wavelength photons. The study will involve materials of interest to the Air Force with emphasis on bond-breaking processes involving substrate and/or adsorbed overlayer. Detailed characterization of the surface structures before and after exposure to the radiation will be accomplished using a variety of surface spectroscopies and high-resolution electron microscopy to study the electronically induced surface structural changes in optical and electronic materials.

TITLE

Fundamental Dynamics of Ocean Structures and Nearshore Circulation

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. R. T. Hudspeth

(503) 754-3631

Oregon State University
Ocean Engineering Program
Corvallis, OR 97331

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Eugene A. Silva (202) 696-4358

SERVICE

ONR

ABSTRACT

This is a multidisciplinary research effort being conducted by members of the Ocean Engineering, Mathematics, and Oceanography faculties at Oregon State University. The research addresses the dynamics of rigid and highly deformable bodies under wave and current forcing, including nearshore environmental effects. It addresses the complete spectrum of ocean structures required to meet Navy missions from deep water compliant structures to nearshore rigid structures. The new research facilities provide a critical new capability for validating theoretical work done under this project and for future research.

A unified theory for predicting wave and current forces on compliant structures will be developed using the theory of chaotic dynamic systems, and new modelling approaches will be established to describe the complex coupled behavior of large, highly deformable bodies tethered or towed in waves. The nonlinear dynamics of complexly connected systems of bodies and long mooring lines will be pursued with emphasis on systems of interconnected long segments and the torsional and tensile properties of cables. Research will also be done on how best to process wave data to establish wave group properties and on nearshore edge wave effects on structures.

Research facilities acquisition includes procurement of a new tow carriage for an existing large wave tank that will allow a broad range of motions to be applied to test bodies during a tow. Directional spectral wavemakers will be purchased for a rectangular wave basin, and a spiral wavemaker is being built for a circular wave tank.

TITLE

Radio Experiments and Science Using the HIPAS Facility

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. A. C. Ferraro

(814) 865-6337

Pennsylvania State University
Communications and Space Sciences Laboratory
University Park, PA 16802

ADDITIONAL PARTICIPATING INSTITUTIONS

University of California at Los Angeles

SCIENTIFIC OFFICER

Dr. Richard G. Brandt

(818) 795-5971

SERVICE

ONR

ABSTRACT

The objective of this program is to further explore ELF/VLF generation from modulation of the complex current system present in the polar regions. Many basic questions need to be answered in order to further identify the feasibility of using this technique in a communications system. It is the purpose of this program to conduct research of three years duration centered around the newly installed, ONR-established ionosphere heating facility, HIPAS, near Fairbanks, Alaska. Consideration is given not only to heating but to diagnostics for the D, E, and F ionosphere regions relevant to communication applications and relevant theory.

Diagnostics include: (1) Wave interaction measurements for electron density profiles of the lower ionosphere. These supplement the ionosonde data at HIPAS for F-region studies. Wave interaction requires lower power heating from the HIPAS heater, or it can be used to detect ionospheric effects of high power heating. (2) Partial reflection measurements to provide information on the dynamics of the lower ionosphere. Data are in terms of winds, planetary scale oscillations, gravity waves and small scale oscillations. The HIPAS heater serves as the diagnostic source for partial reflection measurements.

Generation of ELF/VLF from modulation, by high power heating, of the polar electrojet will be pursued. Nonlinear excitation of low frequency waves by the interaction of two high frequency waves to be produced with the HIPAS facility will be examined.

In addition, a new F-region ionospheric heating measurement technique is proposed. Since it has been shown that ordinary mode incident wave energy can couple into extraordinary energy at the X=1 level for the critical coupling angle. There will be a region on the ground where the ordinary mode reflected amplitude will be very depressed. This will be experimental

proof of this classical coupling theory. Since the resultant extraordinary energy can be deposited in the F-region, new explorations of short scale irregularities, large scale irregularities, and production of extrathermal electrons are possible. These results will have major implications for ionospheric heating experiments and applications.

TITLE

The Marine Atmosphere on the Fleet Scale

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Christopher W. Fairall

(814) 863-3934

**Pennsylvania State University
Department of Meteorology
Walker Building
University Park, PA 16802**

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Robert F. Abbey, Jr. (202) 696-4124

SERVICE

ONR

ABSTRACT

This program combines in-situ and remote sensing instrumentation, data processing and analysis, model development, and theoretical studies into a coherent approach to understanding the mesoscale atmospheric environment over the ocean. The program is a cooperative effort between research meteorologists and engineers at the Pennsylvania State University (SU), the National Oceanographic and Atmospheric Administration's Wave Propagation Laboratory (NOAA/WPL) and the Naval Environmental Prediction Facility (NEPRF).

The dominant focus of the program is the understanding of the evolution of the marine planetary boundary layer (MPBL) through the development and use of ground based remote sensors to probe its vertical structure in considerable detail. The key parameters of concern are MPBL moisture, temperature and wind. This program is the first of its kind to have access to extremely high temporal resolution, of the order of minutes, data in the MPBL.

The program integrates instrumentation development, field experimentation and numerical modeling, leading to the development of operational prediction models suitable for use at central site forecast centers or at remote sites on land or at sea.

TITLE

Integrated Program for Modeling and Remote Sensing: Development of a Nowcasting Capability for the California Current

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. William A. Nierenberg

(619) 452-2826

University of California at San Diego
Scripps Institution of Oceanography
Mail Code A-024
La Jolla, CA 92093

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Thomas W. Spence (202) 696-4112

SERVICE

ONR

ABSTRACT

This program is an integrated, interdisciplinary research effort in numerical modeling and remote sensing to understand the mesoscale variability of the eastern Pacific Ocean. The principal objective of the program is to develop a numerical, nowcasting capability for the mesoscale variability in the dynamic height and subsurface thermal structure off the California coast as a prototype for such activities elsewhere in the world's oceans. The program will include scientists from the Naval Ocean Systems Center (NOSC), the Naval Ocean Research & Development Center (NORDA) and Seaspace Corporation.

Numerical models that will be employed include basin scale quasigeostrophic and/or primitive equation ocean models with realistic topography and forcing, a regional scale ocean model with very high resolution off the California coast that is nested in the basin scale models, a one-dimensional ocean mixed layer model, and a mesoscale atmospheric model that interacts with the ocean models. The models will be used to determine the dominant physical processes influencing mesoscale ocean variability, and to investigate strategies for data assimilation.

The modeling activity will be complemented by a broad observation program using both in-situ and satellite remote sensing platforms. Data from a wide variety of remote sensors will be analysed for their spatial information content, and will be combined with crucial in-situ observations to provide a synergistic view of ocean mesoscale processes.

TITLE

From Mixing to Mesoscale

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Michael C. Gregg

(206) 543-1353

University of Washington
Applied Physics Laboratory
1013 N. E. 40th Street
Seattle, WA 98105

ADDITIONAL PARTICIPATING INSTITUTIONS

University of California at San Deigo

SCIENTIFIC OFFICER

Dr. Thomas W. Spence

(202) 696-4112

SERVICE

ONR

ABSTRACT

This program addresses turbulent mixing processes in the ocean on space scales from 1cm to 100km. The program involves ocean scientists from the University of Washington's Applied Physics Laboratory (UW/APL), the Naval Ocean Research & Development Activity (NORDA) and the Naval Research Laboratory (NRL).

The mechanisms of internal wave breakdown in the thermocline leading to turbulence will be sought with simultaneous visualizations and microstructure measurements. Starting with a commercially available acoustic echo sounder, a device suitable for work in the main thermocline will be developed and used in a microstructure and dye release experiment.

Indirect methods used to infer flux across constant density surfaces in the ocean from microstructure measurements will be tested against laboratory measurements. The experiments will be simulated numerically in order to provide a more complete understanding of the relevant energetics.

Numerical simulations are also being used to explore dynamical interactions having length scales of the order of 10km, the least understood scale range in the ocean. Mixing will be incorporated into the models in order to test the sensitivity of 10km scale processes to this much smaller scale exchange mechanism.

TITLE

Center in Theory and Analysis of the Geo-Plasma Environment

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Robert W. Schunk

(801) 750-2974

Utah State University
Center for Atmospheric and Space Sciences
Logan, UT 84322-3400

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Lt. Col. James P. Koerner (202) 767-4960

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - Investigate high latitude ionospheric dynamics. Study the production, transport and decay of ionospheric irregularities and associated instabilities. Investigate the coupling between the high, middle and low latitude ionosphere. Develop a combined ionosphere-thermosphere model. Investigate ionosphere-magnetospheric coupling on auroral field lines. Assess effect of above phenomena of AF systems.

APPROACH - Investigate the effect of multi-cell convection patterns, plasma blob formation, and multiple arcs on the high-latitude ionosphere. Investigate the coupling of high, middle, and low latitude regions of the ionosphere during the early stages of magnetic storms and substorms. Construct a numerical model of the earth's upper atmosphere and couple it to our global ionospheric model. The combined ionosphere-thermosphere model will be used to investigate the effects of plasma convection, particle precipitation, and plasma blobs on the ionosphere-thermosphere system.

TITLE

Surface Reactions in the Space Environment

PRINCIPAL INVESTIGATOR AND INSTITUTION

Profs. Norman H. Tolk and Richard F. Haglund, Jr. (615) 322-2828

Vanderbilt University
Department of Physics and Astronomy
Center for Atomic and Molecular Physics
Nashville, TN 37235

ADDITIONAL PARTICIPATING INSTITUTIONS

Northwestern University

SCIENTIFIC OFFICER

Lt. Col. Larry W. Burggraf (202) 767-4960

SERVICE

AFOSR

ABSTRACT

OBJECTIVE - The objective of this research is to understand interactions of ground state and excited state oxygen atoms with spacecraft materials (including optical materials, polymers and semiconductors) leading to damage of surfaces and/or producing fluorescent radiation. Synergistic damage due to combined particulate and ultraviolet photon radiation will also be studied. Critical to the effort will be the construction and characterization of an approximately 5 eV ground state oxygen atom source.

APPROACH - The research team will employ 5 eV variable-energy atomic oxygen source to studies of desorption and glow on model materials of interest to the Air Force with emphasis on bond-breaking processes involving substrate and/or absorbed overlayer. Detailed characterization of the surface structures before and after exposure to atomic oxygen beams will be accomplished using a variety of surface spectroscopies and electron microscopy. Laser induced fluorescence and fluorescence spectroscopy will be used to monitor the desorbed products. Frequency-doubled dye laser, synchrotron uv sources, and free electron laser sources will be used to study the photon-particle synergistic damage in these materials. Desorption yield measurements and kinematically complete experiments will be studied as a function of the critical parameters such as the energy state of the atomic oxygen, the temperature and the pulse-probe time delay to understand electronically induced defects.

TITLE

Data Telemetry, Assimilation, and Ocean Modeling

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Robert C. Beardsley

(617) 548-1400

Woods Hole Oceanographic Institute
Department of Physical Oceanography
Woods Hole, MA 02543

ADDITIONAL PARTICIPATING INSTITUTIONS

Massachusetts Institute of Technology, Harvard University

SCIENTIFIC OFFICER

Dr. Thomas W. Spence (202) 696-4112

SERVICE

ONR

ABSTRACT

This program explores new instrumentation, platforms, remote sensing and data handling techniques, and models of the ocean that will allow major advances in ocean understanding over the next decade.

The instrumentation development will merge floats and moored acoustic tomography to measure ocean currents and density structure on basin scales. The key element of the platforms component of the program will be long time moorings from which data is telemetered in real time. Four different telemetry approaches will be explored. One approach uses a permanent surface tether that continuously transmits its data. Two other approaches use sub-surface to transmit their data. The last approach uses a sub-surface data collector that continuously transmits through the ocean using acoustic frequencies.

Remote sensing focuses on the development of new methods of retrieving ocean data from the next generation of ocean satellites such as the Topography Experiment (TOPEX) satellite. Data handling focuses on the development of real time data assimilation technology to continuously fold data into ocean prediction models. The ocean modeling component of the program focuses on developing a hierarchy of user-friendly numerical ocean circulation models.

J. PROPULSION TECHNOLOGY

Services' Areas of Emphasis:

Advanced Propulsion Systems (ARO)

Fast Reaction Kinetics of Energetic Materials (ARO)

Turbulent Reacting Flows (AFOSR)

TITLE

Shock Induced Mixing in Supersonic Combustion

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Frank Marble

(818) 356-4784

California Institute of Technology
Department of Mechanical Engineering
Pasadena, CA 91125

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Julian Tishkoff

(202) 767-4935

SERVICE

AFOSR

ABSTRACT

Description: A team of six senior faculty members have arranged to commit substantial time of three major experimental facilities. The research divides naturally into four thrusts: shock-induced mixing and reaction, details of vortex combustion, shock interaction with a reacting shear layer, and analytical and computational support for all fields. One senior faculty member will direct the activities in each of the above areas, and the Principal Investigator will coordinate the research in these areas, oversee budgetary activities, organize interaction with Air Force and with other laboratories, arrange for briefings, visits and other administrative matters.

TITLE

Supersonic Combustion

PRINCIPAL INVESTIGATOR AND INSTITUTION

Dr. Craig Bowman

(415) 723-1745

Stanford University
Department of Mechanical Engineering
Stanford, CA 94305-6060

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Julian Tishkoff

(202) 767-4935

SERVICE

AFOSR

ABSTRACT

Description: The effort comprises three interrelated parts: an experimental study of mixing and reaction in a supersonic plane mixing layers; development of laser-induced fluorescence techniques for time-resolved two-dimensional imaging of species concentration, temperature, velocity and pressure in supersonic reacting flows; stimulation and modeling of supersonic flows with mixing and chemical reaction. A close-coupling between these efforts will be maintained in order to maximize understanding of supersonic combustion flows.

TITLE

Center for Fast Reaction Kinetics of Energetic Materials

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Curt Wittig

(213) 743-6389

University of Southern California
Chemistry Department
Los Angeles, CA 90089-0484

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. Robert W. Shaw

(919) 549-0641

SERVICE

ARO

ABSTRACT

The Center will be built from a solid nucleus of recent research accomplishments germane to energetic materials. Sophisticated experiments will be combined with state-of-the-art calculations to produce a methodology for studying the inherently complex phenomena encountered in this field. Three complementary experimental thrusts will focus on particular issues such as:

- o Reaction path specificity brought about by the ordered environment of condensed materials,
- o Production, detection, and fate of high energy species (internal and translational degrees of freedom), and
- o Chemical and physical interactions of such species at surfaces.

The experiments are based upon recent and ongoing work and rely heavily on commercially available technology. The investigator's expertise in kinetics, dynamics, spectroscopy, and ab initio calculations will be combined in each of the three major thrust areas. The Center will provide graduate student fellowships, postdoctoral stipends, and a distinguished lecture series. The university will provide funds for preparing and distributing a bimonthly newsletter, organizing a yearly conference, bringing in prospective Army fellows, and running a summer school. Provisions will be made for fellows to spend a year of their graduate studies at an Army laboratory and special postdoctoral appointments will be made in which the recipients spend a year and a half each at the university and at an Army laboratory.

TITLE

Center for Advanced Propulsion Systems

PRINCIPAL INVESTIGATOR AND INSTITUTION

Prof. Gary L. Borman

(608) 263-1616

University of Wisconsin at Madison
Department of Mechanical Engineering
Madison, WI 53706

ADDITIONAL PARTICIPATING INSTITUTIONS

SCIENTIFIC OFFICER

Dr. David M. Mann

(919) 549-0641

SERVICE

ARO

ABSTRACT

The research at this Center will focus on basic programs which will result in improved fuel economy with increased system power to volume ratio. The major thrust of the program is directed to reciprocating engines. Four areas will be investigated:

- o Engine combustion research including heat transfer, internal fluid mechanics, sprays and fuels effects;
- o Fundamental studies of fluid mixing, turbulence modeling and particle laden flows directed toward obtaining methods to be used in the development of turbines and turbomachinery;
- o Materials investigations with the goal of understanding techniques of evaluation under actual engine conditions for ceramics and fiber reinforced materials;
- o Lubrication experiments with emphasis on understanding the influence of oil formulation factors on system design performance.

The Center's faculty will provide graduate student training and will also interact with Army laboratory scientific personnel through outreach seminars, workshops, exchanges of personnel and cooperative working groups.

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