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NSF
Science and Technology Centers

BACKGROUND

The National Science Foundation (NSF) established the Science and Technology Centers (STC) Program in 1987 to fund important basic research and education activities and to encourage technology transfer and innovative approaches to interdisciplinary problems. The centers have the opportunity to explore new areas and build bridges among disciplines, institutions, and other sectors. They offer the basic research community a significant mechanism to take a longer term view of science and explore better and more effective ways to educate students. Specifically, center support enables academic research teams to:

- Exploit opportunities in science and engineering where the complexity of the research problems or the resources needed to solve them require the advantages of scale, duration, facilities, or collaborative relationships that can best be provided by campus-based research centers;
- Involve students, research scientists, and engineers from academia, industry, nonprofit organizations, and Federal laboratories in partnerships to enhance the training and employability of professionals with an awareness of potential applications for scientific discoveries;
- Receive long-term, stable funding at a level that encourages risk-taking and ensures a solid foundation for attracting quality undergraduate and graduate students (with special emphasis on women and minorities) into science and technology careers;
- Facilitate the transfer of knowledge among academia, industry, and national laboratories.

Two competitions have led to the establishment of 25 comprehensive science and technology centers—11 in FY 1989 and 14 in FY 1991. The distribution of these centers by scientific field is: six in the biological sciences, three in computer and information science and engineering, one that spans both behavioral science and computer and information science, five in the geosciences, and ten in the mathematical and physical sciences. The centers have steady-state budgets, the average being $1.9 million in 1992. This brochure provides a brief summary of administrative (including telephone and fax numbers) and scientific and educational information on each Center.

CENTER FOR
UNIVERSITY OF VIRGINIA

NSF Directorate: BIO | Established in 1991

Center Director:	Dr. Gene D. Block
Address:	Biology Department Gilmer Hall University of Virginia Charlottesville, VA 22901
Phone:	(804) 982-5480
Fax:	(804) 982-5626
E-Mail:	gdb@virginia.edu
Administrative Contact:	Becky Abell
Phone:	(804) 982-5612
E-Mail:	clock@virginia.edu
NSF Technical Coordinator:	Dr. Kathie Olsen
Phone:	(202) 357-7040
E-Mail:	kolsen@nsf.gov

Research Objectives

The Center for Biological Timing brings together individual investigators from the University of Virginia, Northwestern University, and Rockefeller University to undertake research in three areas.

- *The molecular and cellular basis of biological oscillations*: Research focuses on the role of transcriptional and translational events, the participation of second messenger systems, and the role of membrane potential/membrane conductances in the generation and control of oscillations.
- *The systems-level analysis of the interrelationships among elements in the timing system*: Research focuses on identification and study of entrainment pathways for circadian rhythmicity and on the study of multioscillator organization and complexity.
- *How the timing system regulates rhythmic processes and behaviors*: Research focuses on both neural and hormonal outputs.

To deal with the complexity of the analysis of periodic data, the Center has established a biomathematical group. This group consists of a biophysicist, mathematician, statistician, neuroendocrinologist, and a rhythms biologist. This distinctive composition fosters a coherent and rigorous quantitative framework centered on the specialized analysis of temporal structure in biological systems.

Research Achievements

Center laboratories have demonstrated, for the first time, circadian rhythms in membrane conductance of individual neurons maintained in low density in dispersed cell culture. This demonstration of the capacity of individual neurons to act as biological clocks opens up new and exciting opportunities for the cellular and molecular study of circadian rhythms. Center investigators also have continued to exploit the *tau* mutant hamster model, developed in a Center laboratory. Recent experiments reveal that, in addition to the effects of this mutation on the circadian clock, the mutation also affects inter-pulse interval in growth hormone secretion. The Center's molecular biology group reports an important technical breakthrough with the successful monitoring of rhythmic *cab* gene expression in plants using a luciferase assay. The Center's biomathematical group continues to develop *NeuroDynamix*, an integrated set of computer models that simulate the dynamic properties of individual neurons and the interactions between neurons. The group is also developing explicit algebraic conditional probability statements to evaluate temporal coupling between two or more pulse trains. Overall, the Center is developing a highly integrated multidisciplinary research program that breaks down traditional departmental boundaries and allows for a productive coordinated research effort.

Educational Achievements

The Center for Biological Timing has initiated a number of educational programs. In January it hosted its first Annual Scientific Symposium on the molecular basis of biological timing. In February the Annual Industrial Symposium, held at the Center for Innovative Technology, featured experts in several areas, including biological clocks and safety in the work place. Beginning in July 1992 the Center will sponsor an intensive four-week course in biological timing. The course will consist of morning lectures, afternoon laboratories and workshops, and evening scientific lectures. Twenty faculty members will participate in this effort. The Center also sponsors summer undergraduate research, faculty sabbatical visits, weekly informal and monthly formal seminars and a new technology tutorial. An aggressive minority outreach program provides seminars by Center faculty to small colleges and institutions with large minority enrollments. In addition, a new high school outreach program, which provides Saturday workshops on biological timing, will bring high school teachers into research laboratories this summer. Following their summer research internship, the teachers will have an opportunity to attend a national scientific meeting.

CENTER FOR
UNIVERSITY OF CALIFORNIA, DAVIS

NSF Directorate: BIO | Established in 1991

Center Director:	Dr. George Bruening
Address:	Plant Pathology, 275 Mrak Hall University of California Davis, CA 95616
Phone:	(916) 752-3474
Fax:	(916) 753-2697
E-Mail:	gebruening@ceprap.ucdavis.edu
Administrative Contact:	Stephen McGloughlin
Phone:	(916) 757-3310
E-Mail:	sdmcglouglin@ceprap.ucdavis.edu
NSF Technical Coordinator:	Dr. Philip Harriman
Phone:	(202) 357-9687
E-Mail:	pharrima@nsf.gov

Research Objectives

The research will be conducted in collaboration with the UC Berkeley, Cornell University, University of Wisconsin, Scripps Clinic and Research Foundation, and Calgene, Inc. The goal of the Center is to develop a detailed understanding of the interactions of plants with their pathogens in molecular genetic and biochemical terms and to use this information in engineering new genes for resistance against pathogens, including viruses, bacteria, fungi, and nematodes. Emphasis will be on the tomato as a model crop with particular technical advantages. The Center has three specific research objectives:

- To isolate and characterize genes and gene products that mediate recognition of pathogens by both resistant and susceptible plants. Response-specific gene products will be manipulated to confirm their role in disease regulation and, where possible, exploited to enhance genetic resistance and increase the durability of resistance against evolving races of pathogens.
- To elucidate molecular and biochemical bases of signal transduction events that occur differentially in resistant and susceptible interactions with cellular pathogens. Identified molecular determinants of disease, both pathogen- and host-specified, will guide the design of novel approaches to achieving resistance.
- To develop new strategies for genetically interfering with virus increase or movement in the host plant or transmission to new host plants. Several approaches are being pursued in parallel which, in combination, may provide durable engineered resistance.

Research Achievements

The Center's main research theme is the isolation and characterization of genes from tomato and tomato pathogens that regulate both susceptibility and resistance to disease. Center research is directed at genetically engineering new resistance genes or increasing the effectiveness of available genes; both are of great value for the economical and ecologically sound control of crop disease. Chromosome walking and transposon tagging are two complementary approaches used to isolate and clone single dominant tomato genes known to condition resistance against several plant pathogens: root-knot nematode (resistance gene: *Mi), Phytophthora infestans (Ph), Alternaria alternata f.sp. lycopersici (Asc)*, and *Pseudomonas syringae pv. tomato (Pto)*. Additional disease response genes will be cloned and characterized from temporal cDNA libraries of genes induced by pathogens and pathotoxins in cells synchronously undergoing stress or necrosis. The response genes from both resistant and susceptible plants will be identified by subtractive hybridization against control plant gene transcripts. Efforts to engineer new resistance genes focus on three general under- or unexploited approaches to controlling plant viruses: inhibition of virus-specified enzymes that promote disease, preventing virus spread by interfering with virus-movement mechanisms, and engineering potential cells with a virus-sensing, self-destruct mechanism designed to limit spread of the virus. CEPRAP is establishing plant transformation and cell micromanipulation facilities. These center-dependent functions will serve as resources for both Center and non-Center scientists.

Educational Achievements

CEPRAP has established outreach ventures with schools (K-12) and junior colleges, including D-QU, a Native American postsecondary institution. Primary emphasis is placed on recruiting students from these underrepresented groups. The Center's goal is to bring the excitement of science to students and provide an enlightened forum for dealing with concerns regarding the social impact of biotechnology. Center members are active in seminars and courses aimed at high school teachers and are also heavily involved in the new California Statewide Biotechnology Education Outreach Initiative, which is developing long-term, community-based education programs. Through the Junior Aggie Summer Research Apprenticeship Program, high school students gain hands-on working experience on laboratory projects. Through the University of California Extension channels, an understanding of biotechnology will be conveyed to the general public. CEPRAP's unique outreach initiative centers on a computer-based multi-interactive media vehicle. Utilizing the existing equipment and technology assets of schools in the surrounding areas, CEPRAP will bring computer-based training in biotechnology to the classroom.

CENTER FOR
CALIFORNIA INSTITUTE OF TECHNOLOGY

NSF Directorate: BIO | Established in 1989

Center Director: Dr. Leroy E. Hood

Address: University of Washington
School of Medicine
Department of Molecular Biotechnology
4909 25th Avenue, N.E.
Seattle, Washington 98195

Phone:
Fax:
E-Mail:

Administrative Contact: Ursula Petralia
Phone:
E-Mail:

NSF Technical Coordinator: Dr. Gerald Selzer
Phone: (202) 357-7652
E-Mail: gselzer@nsf.gov

Research Objectives

The primary objective of the collaborating scientists from the University of Washington, the California Institute of Technology, and the Jet Propulsion Laboratory is to improve upon and integrate the most advanced techniques in genetic engineering, protein and DNA chemistries, and computational analysis in order to develop new technology to speed research on the structure and functions of genes and their protein products. These efforts ultimately will lead to a fundamental change in the understanding and practice of molecular biology. The new technology will be transferable to biological scientists in academia and industry. Projects include development of new and more sensitive methods for determining the sequences of DNA and proteins, new fully automated instrumentation for DNA fingerprinting, and the development of powerful new super-computing hardware for analysis of large data bases.

Research Achievements

The Center has developed powerful new tools that will have great impact on the practice of biology:

- New techniques are being developed for generating and computationally analyzing two-dimensional protein fingerprints. These techniques are key to determining how complex protein profiles change in cells during development. These approaches are being applied to the study of 50-70 DNA binding regulatory proteins responsible for early sea urchin development.

- A new solid phase protein sequencer employing a novel chemistry and automated analysis by mass spectrometry has been developed with the potential for analyses that are 10-100 fold more sensitive.

- New and rapid techniques are being developed for large-scale DNA sequencing. These include the development of new chemistries, the automation of many of the steps in the process, the development of a second generation, automated fluorescent sequencer, and the development of new algorithms and computing tools to handle the enormous influx of information provided by these techniques. DNA sequence analysis is one of the most fundamental and important tools of modern biology. These tools are used to analyze the T-cell receptor immune gene families of humans and mice.

- A novel, fully automated instrument is being developed for DNA fingerprinting that will be key to the genetic mapping of human and animal chromosomes. These techniques will provide molecular biologists with a powerful new tool for exploring fundamental genetic mechanisms. These tools are used to identify the human immune receptor genes that predispose to autoimmune diseases such as multiple sclerosis.

- Powerful new computing chips are being designed that will allow the analysis of biological information tens of thousands of times faster than is now possible with simple computers.

Educational Achievements

The Center has implemented a week-long course in molecular biotechnology for students at the university level and beyond. The course focuses on an integrated, multidisciplinary approach to modern biology, teaching both the theory and techniques of molecular biotechnology, including protein separation, detection, isolation, and microsequencing; DNA chemistry, mapping and sequencing; mass spectrometry; and the use of novel computer hardware and software for the analysis of biological data. It has also implemented one-day briefings in biotechnology. Topics range from contemporary issues facing biology to techniques of biotechnology, microchemical instrumentation, immunology, tools for biotechnology, biologic computation, and the Human Genome Program.

The Center is sponsoring a one-week summer institute for selected high school teachers from minority schools. Through the institute, these teachers will learn modern techniques in molecular biology and develop specific laboratory projects that can be conducted in their classrooms. During the following academic year, the teachers will receive equipment, materials, and support to carry out the projects. In addition, a "Frontiers in Biology" lecture series will be directed at the teachers and their students.

CENTER FOR
UNIVERSITY OF ILLINOIS,
URBANA-CHAMPAIGN

NSF Directorate: BIO | Established in 1991

Center Director:	Dr. Paul C. Lauterbur
Address:	Biomedical Magnetic Resonance Laboratory University of Illinois 1307 West Park Street Urbana, IL 61801
Phone:	(217) 244-0600
Fax:	(217) 244-1330
E-Mail:	bmrl@bmrl.med.uiuc.edu
Administrative Contact:	Claudia Washburn
Phone:	(217) 333-3162
E-Mail:	washburn@bmrl.med.uiuc.edu
NSF Technical Coordinator:	Dr. Kathie Olsen
Phone:	(202)-357-7040
E-Mail:	kolsen@nsf.gov

Research Objectives

The goal of the Center is to develop the world's most advanced magnetic resonance imaging instrumentation for the study of living organisms, individual cells, live animals, and humans and to apply it to the most challenging problems in the life sciences, with a specific focus on brain physiology, anatomy, and function. Five institutions are involved: the University of Illinois, the Lawrence Berkeley Laboratory, the Texas Accelerator Center, the University of Chicago, and the IBM Watson Research Laboratory. The two principal elements of the research program are:

- *The development of magnetic resonance imaging instrumentation* covering a wide range of methodologies and technical approaches, including the design and implementation of a magnetic resonance imaging and spectroscopy system based on a self-shielded superferric four Tesla, one-meter bore magnet, advanced NMR microscopy instrumentation for both imaging and spectroscopy, further development of targetable NMR reagents for the study of perfusion and cell labeling, and the development of tools for advanced image processing and visualization and for mathematical modeling of complex physiologic processes.

- *The application of this instrumentation to the study of a wide range of the most challenging life sciences problems*. Specifically it will be devoted to the understanding of complex biological processes, especially the structure, function, dynamics, and chemistry of the living brain.

Research Achievements

Brain Perfusion: The localization of neuronal function by measurements of local brain perfusion (blood volume and blood flow) using magnetic resonance imaging methods is a major Center goal. The Center has implemented a promising non-invasive method, the arterial spin-tagging technique, and has had excellent success in animal tests. Equipment has been built to make such measurements possible in subsecond times and to implement 3D perfusion imaging. Animal testing of the arterial spin-tagging perfusion method and its enhancements will be completed; it will then be tested on humans.

Brain Spectroscopy: The GSLIM method for combining localized spectroscopy with spectroscopic imaging has been tested on experimental data. The method has also been applied to human brain spectroscopic data. Some of the human brain proton imaging data have been segmented by the Lawrence Berkeley Laboratory.

Brain Imaging: Surface coil microscopes have been built and tested. Theoretical analysis and tests on phantoms confirm that reaching about 50um resolution in the human cortex is a realistic goal.

Tesla Shelf-Shielded 1 Meter Bore Magnet for NMR Spectroscopy and Imaging: Installation is expected to begin in June 1992.

Educational Achievements

Center staff have initiated a biannual course entitled "Functional Imaging of the Brain," cross-referenced in Physiology, Biophysics, and Neuroscience. The course syllabus includes discussions of new breakthroughs in various brain imaging methodologies. Center staff and students are also participating in the biannual course in Biomedical Magnetic Resonance. In 1991 the Center sponsored 11 seminars on functional brain imaging, *in-vivo* spectroscopy, and biological NMR techniques.

The Center will participate in the University of Illinois' Summer Research Opportunities Program, which was established in recognition of the need for inner-university cooperation to increase graduate enrollments from underrepresented minority groups. The program provides minority sophomores and juniors with an opportunity to develop and explore a research topic of their choice.

The Center will serve as a test site during the spring of 1992 for a novel collaboration with the College of Education for science teaching and evaluation in early primary school.

CENTER FOR
CARNEGIE MELLON UNIVERSITY

NSF Directorate: BIO | Established in 1991

Center Director:	Dr. D. Lansing Taylor
Address:	Department of Biological Sciences Carnegie Mellon University 4400 Fifth Avenue Pittsburgh, PA 15213
Phone:	(412) 268-3456
Fax:	(412) 268-6571
E-Mail:	director@a.cfr.cmu.edu
Administrative Contact:	Yvonne Francescon
Phone:	(412) 268-3461
E-Mail:	yvonne@a.cfr.cmu.edu
NSF Technical Coordinator:	Dr. Gerald Selzer
Phone:	(202) 357-7652
E-Mail:	gselzer@nsf.gov

Research Objectives

The Center's research program is divided into technology development and biological research. Technology development centers on light microscope imaging workstations and fluorescence-based reagents. Some of the main objectives are: implementation of two levels of light microscope workstations for biological research and biotechnology, four avenues to fluorescence microtomography (serial-focal deconvolution, scanning confocal fluorescence microscopy, multichannel array-scanning microscopy, and standing-wave fluorescence microscopy), and quantitative graphic display of data. The more powerful version of the workstation has to integrate several modes of light microscopy in a versatile instrument with computer control through a user-friendly interface. A simpler, general purpose workstation will contain a subset of the same capabilities. A common digital image acquisition, formatting, processing, and display protocol will be implemented. Software packages for basic biological applications, offline image analysis, and 3-D processing and display will be developed for a networked approach to challenges raised by biological applications. In addition, advanced software techniques will be used in image analysis. In parallel, brighter and more photostable fluorescent probes will be designed and synthesized to meet the needs of quantitative microscopy. Reagents will be produced based on matching the optimal fluorescent probes with peptides, functional proteins, antibodies, nucleic acids and nucleotides. The instrumentation and probes will be used to extract molecular and chemical information from living cells and tissues, as well as fixed preparations.

Research Achievements

- A robotic multimode microscopy workstation incorporating video-enhanced contrast microscopy, optical sectioning 3-D microscopy, computational deconvolution, random access laser microprobe capabilities, ratio imaging, multicolor fluorescence and steady-state fluorescence anisotropy has been developed and is currently in use for live cell experiments. The instrument is based on a Macintosh computer platform and an intuitive pictorial user interface.
- In collaboration with a corporate sponsor, a second instrument, combining all of the above with laser scanning capabilities, has been developed as an extension of an existing workstation.
- Newly synthesized fluorescent dyes have proved superior to existing options in several respects and have been licensed to a number of companies and coupled to numerous antibodies and nucleotides.
- Some of the fluorescently tagged nucleotide analogues have been used to label gene probes for mapping of single copy genes as well as pulse labeling of tissue for lineage and fate mapping in developmental biology studies, capitalizing on the unique advantages of multimode microscopy.
- A calcium binding indicator of calmodulin has been synthesized and tested *in vitro* and *in vivo*, in conjunction with established calcium probes.
- Steady-state fluorescence anisotropy measurement by ratio imaging has been developed as a new mode of microscopy and applied to the assay of spatial and temporal dynamics of calmodulin interactions in living cells.
- An active program of biomedical collaborations and analytical cytometry development has been initiated.

Educational Achievements

A Careers in Applied Science and Technology Program that will familiarize high school students with Center activities and a training center for light microscopy imaging and fluorescence spectroscopy have been initiated. Center faculty are teaching graduate and undergraduate courses on Biology of the Brain, Molecular Biophysics, and Computational Biology. Courses planned for 1992-93 include: Fluorescence Spectroscopy in Biological Research, Imaging Technology for Biologists, and Practical Aspects of Advanced Light Microscopy.

CENTER FOR
MICHIGAN STATE UNIVERSITY

NSF Directorate: BIO | Established in 1989

Center Director:	Dr. James M. Tiedje
Address:	Center for Microbial Ecology 540 Plant and Soil Science Bldg. Michigan State University East Lansing, MI 48824
Phone:	(517) 353-9021
Fax:	(517) 353-2917
E-Mail:	21394jmt@msu.bitnet
Administrative Contact:	Ann Leipprandt
Phone:	(517) 353-3110
E-Mail:	21394aml@msu.bitnet
NSF Technical Coordinator:	Dr. Joann Roskoski
Phone:	(202) 357-7475
E-Mail:	jroskosk@nsf.gov

Research Objectives

The objective of Center research is to achieve a better understanding of the competitiveness, diversity, and function of microorganisms in their natural and human-made habitats. The research is conducted by microbiologists, soil scientists, molecular geneticists, chemists, engineers, and mathematicians. The research program is organized into several project areas: gene flow and molecular evolution, population diversity, community diversity, novel organisms and processes, biotransformations, and environmental control of gene expression. The research of the Center is focused primarily on the soil and bioreactor habitats, as both have considerable economic importance, offer different advantages for the research, and are not the subject of a focal effort elsewhere in the country.

The Center's basic research on microbial ecology may be used to improve groundwater quality, to develop technologies for hazardous waste disposal, devise means for the control of plant pests, to better understand nutrient cycling in soils, and develop or improve fermentation and other industrial processes. Microbes are also essential to the biotechnology industry, and Center research will help develop genetically engineered microorganisms that are more efficacious and safe for environmental use.

Research Achievements

Considerable research is underway on microbial processes that affect environmental quality. These include studies to determine the diversity and distribution of pathways for

the metabolism of environmental pollutants, the molecular mechanisms operative in their evolution, and how environmental conditions influence these processes. Newly discovered mechanisms for the dechlorination and metabolism of oil and groundwater pollutants are being characterized. In addition, novel methods have been used to isolate organisms that degrade petroleum hydrocarbons under diverse conditions, and novel processes for the synthesis of transmembrane lipids that confer the ability to tolerate extreme conditions have been characterized.

Methods for assessing the genotypic and phenotypic characteristics of microbial populations and communities have been developed and used to assess the impact of agricultural soil management practices on biological processes in soils, to determine the fate of trace levels of synthetic chemicals in a natural pond ecosystem, and to monitor succession and the fate of introduced organisms in bioreactors and intestinal ecosystems. In addition, these methods form the basis for an innovative approach to polyphasic bacterial taxonomy useful in classifying microorganisms. Other research is underway to understand the ecological and genetic processes that give rise to patterns of diversity observed in microbial populations in order to better understand complex phenotypes such as competitiveness of microorganisms in the environment. Also, new tools to study the regulation of gene expression in natural systems are being developed and used to study the role of lignocellulose degrading isoenzymes in soils and the regulation of genes in nitrogen-fixing and antibiotic producing bacteria in response to common environmental cues.

Educational Achievements

The Center's educational outreach program has two primary objectives: first, to enrich the training of students, postdoctoral scientists, and researchers from the academic, commercial, and governmental sectors; and second, to enrich the K-12 science curricula. The Research Internships for Undergraduates Program has funded 18 undergraduates to conduct summer research. The Environmental Gene Probe Workshop provided 40 environmental scientists with theoretical and practical experience in molecular ecology. Other enrichment programs include The Microbial Ecology Forum, Topics in Microbial Ecology Symposia, and The Distinguished Lecturer Series. *The Unseen World*, a program for K-12, provides in-class demonstrations of microorganisms, environmental science, and genetic engineering technology. Also through this program, the Center participates in 4-H programs that target rural students and adults. A newly initiated program, *Science in the City* , developed in cooperation with Detroit Public School teachers, is a two-week summer program for inner city students that includes state-wide field trips and in-classroom laboratory exercises. Center faculty also participate in a high school teacher's Workshop in Environmental and Behavioral Biology that provides background information and materials for "hands-on" laboratory exercises.

CENTER FOR
UNIVERSITY OF PENNSYLVANIA

NSF Directorate: SBE and CISE | Established in 1991

Center Director:	Dr. Aravind K. Joshi
Address:	Center for Research in Cognitive Science University of Pennsylvania 400C 3401 Walnut Street Philadelphia, PA 19104-6228
Phone:	(215) 898-8540/0359
Fax:	(215) 898-0587
E-Mail:	joshi@linc.cis.upenn.edu
Administrative Contact:	Trisha Yannuzzi
Phone:	(215) 898-0333
E-Mail:	trisha@central.cis.upenn.edu
NSF Technical Coordinator:	Drs. Paul G. Chapin & Su-Shing Chen
Phone:	(202) 357-7696 or (202) 357-9569
E-Mail:	pchapin@nsf.gov or schen@nsf.gov

Research Objectives

The goal of the Center is to understand the processes and mechanisms by which humans acquire knowledge about their environment, store and retrieve that knowledge, communicate it to others, and apply it to carry out actions and manipulate their environment. A further goal is to construct computational models of these mechanisms and processes and relate them to the study of machines that can capably perceive the world, learn, reason, communicate, and act. The research is organized into three separate but highly interrelated themes:

- *Perception and Action:* Research spans the processes involved in the first stages of visual and auditory representation of spatial and spectral information to higher order representations of more complex attributes and the storage and retrieval of such representation.
- *Language Learning:* Research focuses on how children develop the abstract representations of language on the basis of their visual and auditory perceptions, thus connecting studies of representation and action to studies of the structure and content of language.
- *Language Processing*: Research combines investigation of formal systems with investigation of computational models, all in the context of empirical study of a wide range of natural languages, thus connecting studies of language proper and the studies of logic and computation.

Research Achievements

A significant part of the working language processing and language acquisition is guided by the question: How much of the structure of the language has to be built-in (innate, in sense, or built into the program), and how much can be acquired from the distributional information available in the speech environment (or large text data bases in the case of a program)? Center interdisciplinary efforts have resulted in the development of new techniques for the automatic discovery of grammars from large corpora and statistical techniques. These were inspired by collateral work on child language acquisition by psychologists and by linguistic techniques developed by linguists and computer scientists. This research lays the foundation for systematically answering the aforementioned fundamental question.

A new kind of explanation for the time course of acquisition through properties of computational complexity has resulted from joint work of computer scientists and linguists. In particular, the assumption that the substitution operation in a grammar is available earlier and the more complex operation of adjunction is available later immediately leads to an explanation of the relative difficulty experienced in the acquisition of seemingly disparate sets of constructions. Visual information comes in various forms, for example, color, brightness, and shading, among others. Perception researchers have recently discovered what may prove to be an entirely new class of visual information and visual information representation of objects: local polarization of scattered light from targets and neural representation in a "polarization difference" or "polarization-contrast" system analogous to the color-difference representation.

Educational Achievements

A comprehensive undergraduate minor in cognitive science was developed and approved by the participating departments and schools. A sequence of new courses have been designed and will be introduced into the program in stages. These will be co-taught by faculty from different disciplines. The first such course, Introduction to Cognitive Science, offered at the sophomore level in Spring 1991 and again in Spring 1992, is co-taught by faculty from computer science and linguistics.

A very successful mentoring program for K-8 uses cognitive science undergraduate and graduate students as tutors. This includes extensive mentoring via projects in mathematical reasoning.

The Kindergarten Colloquium Series fosters teacher enhancement for 40 Philadelphia Kindergarten and first grade teachers, focusing on hands-on activities and children's conceptual development in science.

A large-scale curriculum project for children K-12 uses the Philadelphia Zoo as a laboratory for active exploration of biological concepts and phenomena. Faculty from biology and the Veterinarian School, as well as cognitive science, are involved.

CENTER FOR
RUTGERS UNIVERSITY

NSF Directorate: CISE | Established in 1989

Center Director:	Dr. Daniel Gorenstein
Address:	DIMACS Center Rutgers University Busch Campus P.O. Box 1179 Piscataway, NJ 08855-1179
Phone:	(908) 932-5928
Fax:	(908) 932-5932
E-Mail:	center@dimacs.rutgers.edu
Administrative Contact:	Carol Rusnak
Phone:	(908) 932-5928
E-Mail:	rusnak@dimacs.rutgers.edu
NSF Technical Coordinator:	Dr. Nathaniel Macon
Phone:	(202) 357-7345
E-Mail:	nmacon@nsf.gov

Research Objectives

Researchers from Rutgers University, Princeton University, AT&T Bell Laboratories, and Bellcore are investigating basic topics in discrete mathematics and theoretical computer science. Each year the Center identifies specific areas and invites leading experts to organize research programs in these areas. For the academic year 1991-1992 it is Graph Theory and Algorithms and for 1992-93 it is Combinatorial Optimization. In addition each year the Center runs several week-long workshops in specialized topics outside of the subject of the Special Year. Recent workshops were held on Groups and Computation and Computational Support for Discrete Mathematics.

The objective is to create an environment in which the Center's members interact with long- and short-term visitors as well as participants in the various workshops, leading to major advances in the field. This synergistic interaction will produce new results in both discrete mathematics and theoretical computer science, ultimately finding application in telecommunication, transportation, robotics, computer software design, and many other fields.

Research Achievements

Research activity at DIMACS revolves around the scientific interaction of the Center's permanent members, students, and postdoctorates with long- and short-terms visitors participating in the many working conferences and activities of the special years. The

scientific interactions at DIMACS have reverberated into the community rather quickly. For instance, the workshop on Computer-Aided Verification brought researchers from Government, industry, and academia together to work on formal verification algorithms. Work in the CAD communities at Berkeley, Intel, and Bell Laboratories is tied very closely to the results that emerged from this Workshop, especially the advances in binary decision diagram algorithms and theorem-proving. Also, a proposal for an Intermediate Format for exchanging formal verification tools has been implemented widely in the U.S. CAD community.

As a result of the special year on Complexity Theory of Interaction Computing, a long-standing mystery in the theory of optimization has been explained by indicating why it was hard to find even approximate solutions to the famous max clique problem. The explanation benefited greatly from the interaction between theorists working on combinatorial optimization problems and applied scientists interested in cryptography.

A central problem in information processing involves sorting a partially ordered set by comparisons. Finding a reasonable upper limit on the number of comparisons required for sorting such a set took years. Recently DIMACS participants found good methods for finding the comparisons that achieve the upper limit, which was purely theoretical, in practice. The results should be useful in a variety of practical sorting problems.

As a first step in regaining U.S. leadership in the development of symbolic software, DIMACS held a workshop on Computational Support for Discrete Mathematics. This represents the beginning of a major new initiative in software for discrete mathematics.

Educational Achievements

During the summer, DIMACS co-sponsored two four-week residential programs, one for mathematically talented high school students and one for high school teachers. The student program focused on graphs and algorithms, traveling salesman problems, and covered practical applications as well as theory. The students participated in group problem solving and discussed career opportunities in mathematics/computer science. They also had an opportunity to listen to visiting speakers from industry and academia as well as take several field trips. Most of the original participants attended a follow-up session, which included speakers and new mathematical problems. The program for teachers was designed to attract teachers who would have a significant impact on their districts and beyond. Participants in the Leadership Program in Discrete Mathematics were expected to incorporate what they learned into their school curricula and to discuss these changes with other teachers. The Program focused on introducing students at all levels to the excitement of discrete mathematics. A follow-up session in October revealed the teachers' tremendous enthusiasm in being able to introduce their students and colleagues to these new topics and has injected a new purpose and direction to these teachers' professional lives.

CENTER FOR
UNIVERSITY OF UTAH

NSF Directorate: CISE | Established in 1991

Center Director:	Dr. Donald P. Greenberg
Address:	Computer Graphics 580 ETC Building Cornell University Ithaca, NY 14853-5501
Phone:	(607) 255-7444
Fax:	(607) 255-0806
E-Mail:	dpg@graphics.cornell.edu
Administrative Contact:	Jo Ann Rich
Address:	3190 Merrill Engineering Building University of Utah Salt Lake City, Utah 84112
Phone:	(801) 581-4132
E-Mail:	jarich@cs.utah.edu
NSF Technical Coordinator:	Dr. Merrell L. Patrick
Phone:	(202) 357-7727
E-Mail:	mpatrick@nsf.gov

Research Objectives

The Center operates in cooperation with Cornell University, Brown University, the University of North Carolina, and the California Institute of Technology. The major objective is to build a scientific basis for the next generation of computer graphics software and hardware. Specific research components are:

Modeling: Current geometric modeling systems for objects with complex shapes have been based primarily on boundary representations. Behavioral modeling is in its infancy. New candidates will be explored in order to lay the foundations for a more general scientific base for geometric and behavioral modeling.

Rendering: While the global illumination algorithms that are now used can handle specular environments (ray tracing) and diffuse environments (radiosity), no comprehensive theory exists that can accurately simulate global specular and diffuse reflection. Light-reflection models will be established to simulate reflectance functions and determine illumination methods. Techniques for progressive refinement of rendering methods will be validated through comparison with physical experiments.

Architecture/Software for Visualization: The development of algorithmic improvements and specialized hardware will be pursued to accelerate computations. Emphasis is on displaying the time varying behavior of scientific data or models in real time in order to steer calculations. The development of direct three-dimensional viewing and

manipulation paradigms will be a focus.

Research Achievements

The Center has begun a project on "standards" for software engineering and image exchange. The variety of images the Center uses and produces requires consideration of: uniform treatment of 2D and 3D images, a single image with multiple data arrays, multiple images in a single file, the need for image compression, conversion between formats, and ease of use. Since the standards problem is also common to industry, the standardized, debugged format will be made available to industry when completed.

The Center has achieved a successful remote (at two different Center sites) collaboration between molecular chemists who were investigating superoxide dismutase and experts who were able to take a computer model and make actual 3D parts. The experiment involved modeling and prototyping the molecule using a "stereolithography" prototyping technology. The model being created was a solvent-accessible surface of superoxide dismutase. As a result of this collaboration, the chemists were able to use the sense of touch as a mode for gaining insight. They could actually experimentally fit the physical prototypes together.

The Center has built a large-area tracking system in which the position of a head-mounted display is determined by photogrammetry: a set of cameras on the head frame looks at a grid of LEDs mounted in custom ceiling panels, and the head frame's position and orientation is determined from the known positions of these LEDs. To construct future systems with common, imprecise ceiling tiles and hangers, an automatic system of calibration is needed to determine the precise position of each LED. Through collaboration a self-calibration algorithm has been developed and its effectiveness is being tested.

Educational Achievements

Computer graphics pervades today's technological society and will become even more pervasive. To help students become familiar with and stimulated by ideas motivating and creating the technology, the Center, in conjunction with the Computer Science Department of the University of Utah, operates a five-week summer program for "rising" juniors and seniors in high school from throughout the State. A significant effort is made to attract minorities and women. Center staff developed and taught the two-week long computer graphics portion of the course, which included: concepts from geometry and numerical analysis, image composition and manipulation, how to create graphical models with Alpha_1 (Utah's "in-house" experimental testbed graphics, geometric, and manufacturing modeling environment), and use of the Utah Raster Toolkit for image manipulation capabilities.

CENTER FOR RICE UNIVERSITY

NSF Directorate: CISE | Established in 1989

Center Director:	Dr. Ken Kennedy
Address:	Computer & Information Technology Institute William Marsh Rice University 6100 S. Main Street Houston, TX 77005
Phone:	(713) 285-6077
Fax:	(713) 285-5136
E-Mail:	crpc@rice.edu
Administrative Contact: Phone:	Danny Powell
Phone	(713) 527-6011
E-Mail:	danny@rice.edu
NSF Technical Coordinator:	Dr. Nathaniel Macon
Phone:	(202) 357-7345
E-Mail:	nmacon@nsf.gov

Research Objectives

High-performance computing has become a critical tool of scientists and engineers everywhere. If progress in science and engineering is to continue, faster computers capable of solving larger problems will be required. The only way to continue to increase supercomputer performance at an acceptable rate is to use parallelism on a massive scale. Unfortunately, massively parallel machines have drawbacks. They are hard to program, and they lack algorithms—procedures for computing problem solutions—that can use the parallelism they provide. The Center is committed to a program of research that will make parallel computer systems truly usable—at least as usable as sequential computer systems are today. The research is being conducted by individual investigators at six participating institutions: Rice University, California Institute of Technology, Los Alamos National Laboratory, Argonne National Laboratory, University of Tennessee, and Syracuse University.

Research Achievements

To achieve its goal, the Center is addressing three types of challenges: technological, scientific, and educational.

Technological Challenge: To develop software that will make parallel computers easy to program. This requires new languages and programming support environments that assist the scientist in program preparation, parallelization, debugging, and performance

tuning. A principal subgoal is to make it possible to write machine-independent parallel programs—programs that can be translated to run efficiently on a variety of parallel architectures. The Center has already constructed two different advanced programming systems—one aimed at machine-independent parallel programming in an extended version of FORTRAN and the other supporting programming by parallel composition of programs written in various languages.

Scientific Challenge: To develop parallel algorithms for the broad range of computations currently being performed on sequential machines. The key is to develop algorithms that are scalable in that they can effectively use large numbers of processors to improve performance. Since the CRPC cannot develop all the algorithms that will be needed, emphasis is placed on the discovery of new algorithm design paradigms by which important computational problems may be parallelized. Important new algorithmic methods have already been developed within the CRPC to support fluid flow in porous media, plasma simulations, fluid dynamics, engineering optimization problems, and linear programming.

Educational Achievements

Educational Challenge: To help produce a new generation of scientists and engineers who are familiar with both scientific problem solving and parallel computation. These professionals will multiply the effectiveness of CRPC research by promulgating it throughout the world of scientific computing. The principal strategy is to develop model curricula and short courses that teach the principles of computational science and parallel computation and then export the curricula to educational institutions outside the Center. New graduate programs in Computational Science and Engineering have been developed at Rice, Syracuse University, and the California Institute of Technology; and special opportunities have been created to involve underrepresented minorities in research. Particularly successful has been the CRPC program of workshops designed to expose teachers at minority high schools and middle schools to the opportunities offered by computational science so that members of future graduating classes will seek careers in high-performance computation.

UNIVERSITY OF SOUTHERN CALIFORNIA

NSF Directorate: GEO | Established in 1991

Center Director:	Dr. Keiiti Aki
Address:	Department of Geological Sciences University of Southern California Los Angeles, CA 90089-0740
Phone:	(213) 740-5830
Fax:	(213) 740-0011
E-Mail:	aki@sei.usc.edu
Administrative Contact:	John McRaney
Phone:	(213) 740-5842
E-Mail:	mcraney@sei.usc.edu
NSF Technical Coordinator:	Dr. James H. Whitcomb
Phone:	(202) 357-7356
E-Mail:	jwhitcom@nsf.gov

Research Objectives

The goal of the Center, which is supported by NSF and the U.S. Geological Survey, is to integrate earthquake information for translation into hazard mitigation for societal benefit. The approach is keyed to the development of a framework in which geologic, geodetic, geophysical, and seismological information pertinent to earthquakes in southern California will be integrated for the purpose of developing a time-space dependent probabilistic hazard analysis of the region that may be used as a general basis for predicting the levels of strong ground motions. The research will be conducted in cooperation with the California Institute of Technology, the University of California (Los Angeles, Santa Barbara, San Diego, and Santa Cruz), Columbia, and the U.S. Geological Survey.

The Center's core activities include: establishment of a data center for real-time seismic data acquisition, data archiving and distribution, and data retrieval service; fault-specific geophysical, geodetic, and geologic field studies; analysis of existing and new short-period network data to improve the delineation of active faults; development of a physical model of the earthquake process to establish a physical basis for the characteristic earthquake model; investigation of source, path, and site effects for strong ground motion prediction; regional tectonics, and commencement of a conceptual study for a pilot geotechnical project in an area prone to liquefaction and/or landsliding.

Research Achievements

- Fifteen years of individual investigator research on earthquakes in southern California has taken place under the National Earthquake Hazard Reduction Program. SCEC has succeeded in drawing these individuals together to jointly develop a major project of that research—a probabilistic hazard analysis for southern California (master model). Such master models, representing the integration of a wide range of earth science information, are expected to form the primary basis for future estimates of earthquake hazard in seismically active areas worldwide.

- A regional data center and archive for all earth sciences information pertaining to earthquakes and earthquake hazard in southern California has been established by SCEC at Caltech. The data center will enable center scientists, non-center scientists and ultimately the public at large to access center data bases and other computerized products such as maps, graphics, etc. The data center will also serve as a resource for scientific briefings of the media following major earthquakes.

- SCEC has facilitated installation in southern California of the world's most comprehensive strain monitoring network using the new Global Positioning Satellite (GPS) System technology.

- SCEC has brought to the fore an important debate regarding the importance of fault zone heterogeneity in earthquake mechanics. The resolution of this debate, a new focal point in earthquake research, has important implications with respect to the earthquake potential of active faults.

- With funding from the California Department of Transportation, the County of Los Angeles, and the City of Los Angeles, SCEC has added a geotechnical engineering component to address hazards posed by earthquakes to the region's highways and bridges.

Educational Achievements

SCEC has become the centerpiece for a major outreach effort in earthquake hazard analysis in southern California.

- A Memorandum of Understanding (MOU) between SCEC and the Southern California Earthquake Preparedness Project (funded by the Federal Emergency Management Agency (FEMA) and the California Office of Emergency Services) has been formally established to reach out to public and private sector emergency preparedness groups and impact K-12 science curricula. FEMA has provided funding to facilitate the MOU.

CENTER FOR
UNIVERSITY OF CHICAGO

NSF Directorate: GEO | Established in 1991

Center Director:	Dr. V. Ramanathan
Address:	Scripps Institution of Oceanography University of California (0239) La Jolla, CA 92093-0239
Phone:	(619) 534-8815
Fax:	(619) 534-4922
E-Mail:	ram@ucsd.edu
Administrative Contact:	Lynne Kenney
Phone:	619 534-8815
E-Mail:	ram@ucsd.edu
NSF Technical Coordinator:	Dr. Jay S. Fein
Phone:	(202) 357-9892
E-Mail:	jfein@nsf.gov

Research Objectives

The goal of the Center is to develop the theoretical, observational, and modeling knowledge base required to understand and predict the changing climate and chemistry of earth's atmosphere, be it a result of natural causes or human activities. A major objective is to unravel the role of clouds in climate and chemistry. Clouds, which are believed to play a central role in regulating the radiative heating of the planet and in governing the transport of trace gases, are poorly understood phenomena in earth sciences. Their uncertain role is one of the primary reasons that accurate predictions of global warming are impossible. The Center brings together research groups that have made fundamental contributions in the areas of the greenhouse effect, atmospheric chemistry, climate, and global change. Included are: Scripps Institution of Oceanography (SIO), University of Chicago, University of Maryland, Oregon State University, Princeton University, the University of Stockholm, and research laboratories at Ford Motor Company, Max Planck Institute, National Center for Atmospheric Research (NCAR), and European collaborators from GLOMAC. Researchers will embark on joint aircraft measurements, global model studies, and analyses of satellite data to document and interpret changes in the area of global change.

The Center will use satellite data, participate in the planning of field experiments and gather data needed for atmospheric models, and analyze existing data from major natural and anthropogenic experiments to interpret and model the connection between regional chemistry and climate forcing, the role of clouds in air-sea interactions, and the interaction between ocean warming, climate and atmospheric transport of water vapor and other gases. The Center will assemble a satellite data base for the tropical ocean-atmosphere system, and perform studies of interactions employing a spectrum of

microphysical, chemical, and climate models. The parameterizations used in global models will be tested and used to reconstruct regional distributions of chemically induced radiative forcing of climate during the past century.

Research Achievements

Center researchers, in cooperation with scientists from NASA Ames and NASA Goddard, have designed a field experiment (CEPEX) to test the Pacific thermostat hypothesis. According to this hypothesis, clouds associated with deep convection reflect solar radiation and regulate sea surface temperatures. In the cloud chemistry area, a Center-sponsored workshop held in Germany helped to identify the role of anthropogenic sulfate aerosols in enhancing the solar radiation reflected by the planet: Reflection of solar radiation by sulfates is now recognized to be a major climate forcing term.

To utilize the vast amount of satellite and *in situ* cloud data and to enable estimation of the three-dimensional radiative heating and chemical species transport effects, the Center has developed a computer imaging algorithm that converts the 5-channel AVHRR pixel data from operational, polar orbiting satellites into three-dimensional cloud fields. It has developed a graphics package to portray these clouds on a CRT with realistic perspective and shading. Further development of this package will enable the visualization of numerically modeled (GCM) cloud fields. Center scientists at NCAR and the University of Chicago have assembled a spectrum of cloud scale regional models to understand the regional climate effects of clouds.

Educational Achievements

Center scientists participated in the Scripps Undergraduate Research Fellowship Program, which enables undergraduates to gain firsthand research experience during the summer, and in a science teachers' symposium on climate and global change; produced a video on clouds, which is part of a traveling exhibit geared toward high school students, for the Franklin Institute in Philadelphia; and are working with the Museum of Science and Industry in Chicago to design an Imaging Science permanent exhibit.

The Center plans to produce educational videos and other materials for the museum exhibits on climate and global change at the new Stephen Birch Aquarium, SIO; participate in the educational programs targeting high school students and science teachers; work with undergraduate and high school students during the summer quarter using a Fourier Transform Infrared (FTIR) Spectroradiometer to investigate the effects of urban and industrial pollution on the local atmospheric greenhouse effect in Southern California; work with the California Space Institute to develop video educational materials on climate and global change that can be used as instructional materials; collaborate with NCAR to conduct and support an advanced summer workshop for graduate students; and conduct a NATO Advanced Study Workshop.

CENTER FOR
UNIVERSITY OF CHICAGO

NSF Directorate: GEO | Established in 1991

Center Director:	Dr. Doyal A. Harper
Address:	Yerkes Observatory 373 West Geneva Street Williams Bay, WI 53191-0258
Phone:	(414) 245-5555
Fax:	(414) 245-9805
E-Mail:	cara@oddjob.uchicago.edu
Administrative Contact:	Judy Bausch
Phone:	(414) 245-5555
E-Mail:	jab@tycho.yerkes.uchicago.edu
NSF Technical Coordinator:	Dr. John T. Lynch
Phone:	(202) 357-7894
E-Mail:	jlynch@nsf.gov

Research Objectives

The Center, in collaboration with Princeton University, Boston University, the University of Illinois, University of Colorado, Harvard-Smithsonian Center for Astrophysics, Haverford College, George Williams College, the Adler Planetarium, AT&T Bell Laboratories, and Rockwell International Corporation, will establish an observatory at the South Pole with three instruments designed to probe the far reaches of the Universe at wavelengths ranging from 2 to 3000 microns.

AST/RO (Antarctic Submillimeter Telescope and Remote Observatory) will use a 1.7 meter diameter telescope to survey the Galactic plane, the Galactic Center, and the Magellanic Clouds at submillimeter wavelengths. Taking advantage of the cold, dry polar air, AST/RO will use line emission from atoms and molecules as "probes" to study star formation, the evolution of heavy elements, and the nature of the interstellar medium.

SPIREX (South Pole Infrared Explorer) will use a 60 centimeter diameter near-infrared telescope to search for primeval galaxies and brown dwarf stars and probe the cores of dense star-forming clouds. It will seek to exploit a unique "window" at a wavelength of 2.4 microns in which both atmospheric and celestial sources of "foreground" emission are very small. In this spectral window, Antarctic telescopes may be 200 times more sensitive than telescopes at the best mid-latitude sites.

COBRA (Cosmic Background Radiation Anisotropy) is an experiment that will search for and map anisotropies in the Cosmic Background Radiation at sufficient sensitivity to definitively test current theories of the origin of the Universe and the formation of

galaxies.

Research Achievements

The site for the Center's telescopes has been established, and construction has begun on the first of two laboratory buildings. Approximately one kilometer away from the central dome of the South Pole base, this site should be the finest on Earth for infrared and submillimeter wavelength astrophysics. Preliminary experiments reveal that the background sky temperature and the water vapor content of the polar atmosphere are at least as low as computer models had predicted. The AST/RO telescope and first-generation receivers are nearing completion. This off-axis telescope, with its 1.7 meter carbon-fiber mirror, will be assembled and tested at Boston University in the coming year and then shipped to the South Pole for installation on a building currently under construction. COBRA experiments and engineering continue to advance. Investigations at the Pole with one-meter class instruments have yielded important results about the character of the Earth's atmosphere as well as valuable experience in this extreme environment. Progress has also been rapid in developing new, low-noise, multi-element detectors for the two-meter COBRA telescope now under construction. Under SPIREX, the newest of the three Center experiments, development of the first near-infrared camera to be deployed at the South Pole is progressing rapidly. With this camera, the first tests of the background emission of the Antarctic night sky at infrared wavelengths will be performed.

Educational Achievements

The Center has established an innovative project in science outreach education called the Space Explorers Project. Its target audience is Black students at inner-city Chicago schools. This multi-year program is designed to provide a supportive social environment comprised of scientists, teachers, students, parents, and coaches to provide “hands-on” experiences in sciences related to the mission of the Center. Space Explorers regularly visit laboratories and attend workshops at Yerkes Observatory, the Adler Planetarium, and the University of Chicago campus. Not only have these high school students themselves profited, but they are training to be instructors and mentors to the next generation of Space Explorers.

CENTER FOR
UNIVERSITY OF OKLAHOMA

NSF Directorate: GEO | Established in 1989

Center Director:	Dr. Douglas K. Lilly
Address:	Cooperative Institute for Mesoscale Meteorological Studies University of Oklahoma 410 E. Boyd Avenue Norman, OK 73019-0515
Phone:	(405) 325-3041
Fax:	(405) 325-7614
E-Mail:	dlilly@geoadm.gcn.uoknor.edu
Administrative Contact:	Chris Heath
Phone:	(405) 325-3041
E-Mail:	cheath@geoadm.gcn.uoknor.edu
NSF Technical Coordinator:	Dr. Stephan P. Nelson
Phone:	(202) 357-9431
E-Mail:	snelson@nsf.gov

Research Objectives

The goal of the Center is to develop techniques for the numerical prediction of relatively short-lived and small-scale weather phenomena, especially severe thunderstorms and related events such as low-level wind shear, flash floods, and damaging hail. The CAPS research effort, which includes basic theory, numerical experimentation, and operational testing, is focused on two principal areas: prediction modeling and data assimilation. A new prediction model based on improved understanding of storm physics, advanced numerical techniques, and massively parallel data processing is being developed. The model is dependent on assimilation of current weather data, especially data from the network of Doppler radars now being installed nationwide. CAPS is leading the development of methods by which quantities not observed directly by single Doppler radar can be retrieved from the observations and used to initialize the prediction model.

Future CAPS research will also include:

- study of the fundamental predictability of small-scale weather;
- development of advanced video techniques to permit efficient display and evaluation of weather data.

Research Achievements

CAPS has developed the Advanced Regional Prediction System, which serves as the foundation and computational framework for development of increas-ingly complex and comprehensive versions of the advanced forecast model. Version 1.0 is designed specifically to be run on a variety of computer architectures, particularly parallel architectures, and showed the appropriateness of the new coding scheme for that purpose. Model 2.5 is now in the final stages of testing. It incorporates the necessary physical and computational elements of a prediction model and will allow a wide variety of developmental simulation and prediction studies. Research in data assimilation and retrieval is proceeding on a variety of fronts. Several methods for initializing a model with single Doppler data have shown theoretical success, and studies indicate the availability of multiple Doppler over a larger area than originally expected. Practical assimilation methods for the larger scales, using NMC predictions and other sources of data are under development. Data visualization techniques have been developed and acquired by the Geosciences Computer Network to allow color graphic displays, including animation, of observed or computer meteorological fields.

Educational Achievements

CAPS has initiated and participated in several educational programs. In 1991, with CAPS support, KGOU radio, the OU NPR affiliate, began production of a daily series about the weather, known as WeatherWhys. By September 1991 more than 50 NPR stations coast-to-coast aired the program daily, reaching about one million listeners per week. With support from the American Meteorological Society, programs from the first year will be rebroadcast. Another CAPS educational outreach activity is the Meteorological Applied Problem Solving (MAPS) competition for high school students, which is conducted by the Oklahoma City Community College. In addition, CAPS scientists and programmers were involved as undergraduate student mentors or as lecturers in the 1991 summer Research Experiences for Undergraduates (REU) held at the Norman Weather Center. CAPS will participate again in the summer 1992 REU program.

CENTER FOR SUNY, STONY BROOK

NSF Directorate: GEO | Established in 1991

Center Director:	Dr. Donald J. Weidner
Address:	Department of Earth and Space Sciences ESS 117 SUNY at Stony Brook Stony Brook, NY 11794-2100
Phone:	(516) 632-8241
Fax:	(516) 632-8240
E-Mail:	dweidner@sbccma.sunysb.edu
Administrative Contact:	Shirley King
Phone:	(516) 632-8241
E-Mail:	sking@sbccma.sunysb.edu
NSF Technical Coordinator:	Dr. Daniel F. Weill
Phone:	(202) 357-7807
E-Mail:	dweill@nsf.gov

Research Objectives

The goals of the Center are: to determine, understand, and interpret the properties of Earth materials at high temperature and pressure; design and construct the next generation of high-pressure devices for application in physics, chemistry, and materials science as well as the earth sciences; apply knowledge of experimental geophysics and geochemistry to better understand the Earth's interior and to resolve fundamental questions about the Earth's evolution, structure, and dynamic state; apply high-pressure research to improve understanding of materials and of the interiors of other planets. The research will be conducted by individual investigators at SUNY, Stony Brook, in collaboration with Princeton University and the Geophysical Laboratory of the Carnegie Institution of Washington.

Programs include: the development of larger volume, multi-anvil presses; development of larger dimension, composite diamond-anvil cells, usage of high pressures in synchrotron radiation experiments at Brookhaven; development of a micro-calorimeter that can be used at high pressures; and elasticity measurements. Research will be conducted in high-pressure geophysics, including phase transformations, mineral synthesis and phase equilibria at high pressure, rheology, melts and melting, and computer simulations of materials at high pressures and temperatures. New materials will be synthesized. A program of synthesis and characterization (the growth of single crystals at high pressures and temperatures), hot-pressing of polycrystalline aggregates, and characterization by x-ray, electron microprobe and microscope techniques will be undertaken. The Center will instrument beamlines at the Brookhaven National Synchrotron Light Source facility.

Research Achievements

- New mineral phases have been discovered that contain water and are stable to high pressure and temperature. These minerals may have been a reservoir for water during the early time in the formation of the earth when water could not survive on the surface. They may also hold the key to understanding the origin of deep earthquakes.
- Hydrogen has been compressed to an opaque solid with properties that indicate that it may be metallic or that a metal may be forming. The metallization of hydrogen will provide new insight into the physics of solids.
- By studying micro-sized samples of earth materials at high pressure, insight is gained into the evolution of the earth. Materials with the perovskite crystal structure make up the bulk of the earth, but their synthesis requires high pressure. By characterizing the properties of small synthetic materials, description of the properties of the massive interior of the earth has been achieved.
- Acoustic velocities in the high-pressure phases of olivine have been measured directly as a function of pressure for the first time in a collaborative study with the Australian National University. These data have been used to investigate the chemical and mineralogical composition of the Earth's upper mantle.

Educational Achievements

- A high school student, John Lopez, worked on a project to determine experimentally the melting curve of $CaSiO_3$. The results were reported at the American Geophysical Union meeting and entered in the Westinghouse Science Talent Search. The student was selected as a semifinalist in this national competition.
- Dr. Gabriel Gwanmesia (native of Cameroon), who received his Ph.D. from SUNY, Stony Brook, joined the faculty of the Department of Physics and Astronomy at Delaware State College, a predominantly Afro-American college. He will be bringing undergraduate students from Delaware State to visit and work in the Center.
- The Center has initiated a summer program for undergraduates majoring in the physical sciences. Students will work closely with Center staff during the summer and participate in field trips to the research laboratories at Princeton and the Geophysical Laboratory.
- The Center has developed an interdisciplinary multimedia educational program designed for precollege students. A pilot program is being offered to local junior and senior high schools.

CENTER FOR
KENT STATE UNIVERSITY

NSF Directorate: MPS | Established in 1991

Center Director:	Dr. J. William Doane
Address:	Liquid Crystal Institute Kent State University Kent, OH 44242
Phone:	(216) 672-2654
Fax:	(216) 672-2796
E-Mail:	alcom1@kentvm.kent.edu
Administrative Contact:	Elaine Landry
Phone:	(216) 672-2654
E-Mail:	elaine@queenofhearts.kent.edu
NSF Technical Coordinator:	Dr. Robert J. Reynik
Phone:	(202) 357-9791
E-Mail:	rreynik@nsf.gov

Research Objectives

The goal of the ALCOM Center, the Northeastern Ohio consortium of Kent State University, Case Western Reserve University, and the University of Akron, is to advance the science of liquid crystalline materials on both the molecular and macroscopic levels to allow prediction and optimization of their optical behavior.

The research addresses five specific areas: *Synthesis and Formulation of Advanced Materials*: Synthesize novel liquid crystalline materials, including polymers, and formulate associated dispersions, blends, and composites of optical importance. *Physical Properties*: Investigate the interrelationships among the physical properties associated with liquid crystallinity and optical behavior. *Interfaces, Instabilities, and Finite Size Effects*: Measure and analyze the role of surface and finite-size effects in liquid crystalline materials of optical importance. *Theory and Computation*: Predict optical, elastic, hydrodynamic, and phase behavior of liquid crystals based on their molecular structure/composition and boundary conditions. *Electro-optics and Non-linear Optics*: Explore the electro-optical and nonlinear optical behavior of liquid crystalline materials and prototype such devices as spatial light modulators, switchable waveguides, and displays.The National Center for Integrated Photonic Technology, supported by DARPA, and ALCOM share a Resource Facility that provides supplementary synthesis, basic characterization services, optical performance evaluation of materials, and device prototyping. To enhance technology transfer, ALCOM cooperates with the Edison Polymer Innovation Corporation.

Research Achievements

ALCOM research responds to the importance of liquid crystal materials in flat-panel displays, their potential for new optical devices, and their richness in physical and optical phenomena. Collaborative research among the scientists at the three northeast Ohio universities combines polymer and low molecular weight liquid crystals to develop new and improved optical materials. Examples of achievements include the discovery and development of a polymer/gel cholesteric liquid crystal dispersion for flat-panel color displays that exceeds current technology in color brightness and contrast and overall electro-optic performance; the discovery of optical effects involving surface-induced polarization; the first measurement of surface elastic constants of a nematic liquid crystal; and the development of a new infrared method of measuring material concentrations in polymer dispersed liquid crystals important in light modulators. These and similar achievements are possible only because of the collaborative atmosphere and focus of ALCOM.

Educational Achievements

Liquid crystals, rich in easily realized physical and optical phenomena, captivate children's interest. Faculty from the College of Education and ALCOM scientists collaborate in using these materials to excite and educate K-12 students in basic science concepts. High school teachers, recruited through a local six-district educational compact, spend summers at ALCOM developing education/demonstration kits. These hands-on kits contain two levels of instruction (K-6 and 7-12). They are designed to teach fundamental optical and physical principles. Graduate students, who perform the bulk of ALCOM research, also participate in educational activities such as Creative Connections and Upward Bound. In these programs high school students participate in classroom activities and spend several hours in a research laboratory performing simple experiments, such as making a display, using liquid crystal for art, or making microscope observations.

CENTER FOR UNIVERSITY OF ILLINOIS, URBANA-CHAMPAIGN

NSF Directorate: MPS | Established in 1989

Center Director:	Dr. Miles V. Klein
Address:	Materials Research Laboratory University of Illinois 104 South Goodwin Avenue Urbana, IL 61801
Phone:	(217) 333-1744
Fax:	(217) 244-2278
E-Mail:	Miles_Klein@stcs.mrl.uiuc.edu
Administrative Contact:	William A. Dick
Phone:	217-333-1744
E-Mail:	w-dick@uiuc.edu
NSF Technical Coordinator:	Dr. Robert J. Reynik
Phone:	(202) 357-9791
E-Mail:	rreynik@nsf.gov

Research Objectives

The phenomenon of high-temperature superconductivity, the complexity of the materials themselves, and the potential for technological application together present an extraordinary scientific and technical challenge. The Center undertakes to understand the materials and phenomenon as a basis for possible applications by bringing together human resources and facilities from four institutions with strong capabilities in superconductivity, materials research, and education—the University of Illinois, Northwestern University, the University of Chicago, and Argonne National Laboratory. The Center enables a multi-institutional, multi-investigator, fully cooperative research design that capitalizes on the sharing of ideas, samples, and facilities. The research community in industry, academia, and Government laboratories participates selectively in Center collaborations and workshops that focus on key issues for the national basic research agenda.

Research Achievements

The Center is a leading national effort in several materials systems that, in turn, are the basis for center-wide exchange of samples and results. Center scientists produce very high-quality crystals of the 90K superconductor $YBa_2Cu_3O_7$ (YBCO) that have no twin boundaries. Using such "untwinned" crystals, physicists are elucidating those properties that arise from fundamental behavior of both the superconducting and normal state.

Theoretical models of the unusual normal state have succeeded in analyzing a variety of experiments and form the basis for current work on novel mechanisms for the superconducting state.

Layered cuprate compounds presently offer the best opportunity for achieving still higher temperatures at which the material becomes superconducting. Using knowledge of the effect of structure on properties, a team of Center researchers has systematically designed a new class of layered cuprates. Further research on the structural and compositional basis for superconductivity correlates changes in chemical composition with transition temperature. Results have demonstrated the dramatic effect of local defect ordering on superconducting properties. Other work uses new experimental techniques to create defects to improve the current-carrying capacity of the materials, an important feature for applications.

In concert with researchers from industry, the Center is studying thin films and potential devices of the material, $Ba_{1-x}K_xBiO_3$ (BKBO). With its transition temperature of about 30K, simple cubic structure, and favorable superconducting characteristics, BKBO may lead to devices superior to those made from older conventional superconductors—provided that reproducible control of materials growth and processing can be achieved. Center results from the growth of films by metallorganic chemical vapor deposition point to that technique as a possible one to produce high-quality layers for scaled-up production in industry.

Educational Achievements

A primary goal of the Center is the education of graduate and postdoctoral students in a highly stimulating, multidisciplinary intellectual environment. These young investigators will be major contributors to an expanding materials industry in this country. The Center provides the organizational impetus for workshops, interaction with industry scientists, and other professional development opportunities, as well as access to state-of-the-art facilities across four sites with professional help for student users.

The Center has an active educational outreach program to engage undergraduate students in research. Over the past three summers, 43 undergraduates have received Center funds for an 11-week research experience at one of the four Center sites. Other undergraduates participate in research during the academic year. The Center has an aggressive program of workshops for high school teachers to help them incorporate new concepts and experiments into their classes. Other outreach programs attract pre-college students for summer research experiences and for visits to laboratories. All programs emphasize reaching those students whose demographic or financial status may otherwise limit their opportunities for learning and careers in science and technology.

THE GEOMETRY CENTER
UNIVERSITY OF MINNESOTA

NSF Directorate: MPS | Established in 1991

Center Director:	Dr. Albert Marden
Address:	The Geometry Center University of Minnesota 1300 South Second Street Minneapolis, MN 55454
Phone:	(612) 624-5851
Fax:	(612) 626-7131
E-Mail:	am@geom.umn.edu
Administrative Contact:	Angie Vail
Phone:	(612) 626-8323
E-Mail:	angie@geom.umn.edu
NSF Technical Coordinator:	Dr. Alvin I. Thaler
Phone:	(202) 357-3691
E-Mail:	athaler@nsf.gov

Research Objectives

The Center involves collaboration among faculty from the University of Minnesota, Brigham Young, Cornell, Courant Institute, Harvard, Princeton, Rutgers, SUNY (Stony Brook) University of California (Berkeley and San Diego) Yale, as well as the University of Paris XI, the University of Warwick, AT&T Bell Laboratories, and IBM.

The subject of mathematics, an extremely rich and varied territory, has had a tendency to fragment into many subdisciplines, with little communication between them, or their closely related fields, such as computer science. The goal of the Center is to tie these differently perceived fields together under the unifying topic of geometry and geometric representation on the computer. The Center's scientific program is based on a core of scientific investigations whose origins are in both "pure" mathematics and models of physical phenomena. It includes: topology; geometry and symmetry; dynamics; geometric optimization; computational geometry and graphics; and fractal geometry. The Center is building a unified environment that closely integrates research, education and communication, and software and video development in support.

Research Achievements

- A graduate student at Rutgers University has developed the first computer code that can simulate dendritic freezing such as the growth of snowflakes. A postdoctoral student at Courant has developed the first computer code that works for smooth problems such as simulation of the solidification of steel.

- *Word Processing in Groups*, which explains the new theory that allows computers to work directly with the groups of geometry, such as the symmetries of various geometric objects, has been created under Center auspices.
- Software has been developed that allows presentation of two complicated knots of general type and enables one to determine whether or not one knot can be deformed into the other.
- Software has been developed to minimize the elastic energy of curved surfaces in space, and thus to compute and display so-called Willmore surfaces. This will allow the exploration of their geometry, which could resolve several outstanding conjectures.

Educational Achievements

- A two-week intensive summer course, "Geometry and the Imagination," for a mix of high school and college students and teachers, introduces fundamental ideas in current geometry research, using constructive toys, vegetables, mirrors, flashlights, and string. The course, which does not require a math background, has been widely imitated.
- A ten-week summer institute for advanced high school and college students. Students complete a summer-long project in math or computer science using the capabilities of high-performance graphics workstations.
- Production of *Not Knot,* a computer-generated video that uses computer graphics to show what would be seen if one lived in the space surrounding the Borromean Rings with a non-euclidean metric. It features the first ever realistic fly-through of a space with a non-euclidean metric. Audiences range from elementary school children to research mathematicians. The video won highest recognition for scientific visualization from Siggraph in U.S. and Nicograph in Japan.
- A leader in the coordination and dissemination of activities and technology expertise through the NSF-sponsored networks Mathematicians for Education Reform (MER) and Minnesota Mathematics Mobilization (M^3).

CENTER FOR VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

NSF Directorate: MPS | Established in 1989

Center Director:	Dr. James E. McGrath
Address:	Department of Chemistry Virginia Polytechnic Institute and State University Blacksburg, VA 24061-0212
Phone:	(703) 231-5976
Fax:	(703) 231 8517
E-Mail:	timp@vtvm1.cc.vt.edu
Administrative Contact:	Laurie Good
Phone:	(703) 231-4457
E-Mail:	GoodLS@vtvm1.cc.vt.edu
NSF Technical Coordinator:	Dr. Robert J. Reynik
Phone:	(202) 357-9791
E-Mail:	rreynik@nsf.gov

Research Objectives

The primary objective of the Center is to establish and integrate fundamental concepts for the design, synthesis, processing, and manufacture of polymeric adhesives and composites in order to understand and control their properties and performance in engineering applications. The justification for this effort rests on the critical need for a coherent philosophy and systematic methodology for the creation of new and advanced polymeric adhesives and composites that are important to the national economy and essential to the security of the U.S.

The major goal is to achieve and promote a better understanding of the basic science and technology of high-performance polymeric adhesives and composites at the molecular, micromechanical, and interfacial levels to allow correlations and predictions of macroscopic physical behavior. The results and activities will have significant impact on the industrial community, especially the aerospace, automotive, chemical, electronic, and specialized construction industries, wherein materials systems must be designed for maximum durability, reliability, and safety. Education thrusts, an important part of the Center, include continuing education for industrial scientists and engineers, undergraduate teachers, undergraduate students, and outreach to minority institutions.

Research Achievements

The Center has established the first U.S. university facility able to synthesize thermoplastic or toughened thermosetting polymeric matrix materials, process them by conventional and novel prepreg methods, and study the resultant composites at the molecular, bulk interfacial, and macroscopic levels in a fully integrated fashion. This integrated capability for creating and characterizing material systems from their birth (synthesis of new constituent materials) to their limits (lifetime and performance capabilities of engineering components established both experimentally and predictively under service conditions) at one facility is a major achievement of the Center.

Specific advancements include: First synthesis of soluble, amorphous thermally stable polyimide matrix resins with glass transition temperatures above 400 degrees centigrade. Development of new methods for the preparation of micron-sized powders of amorphous and semicrystalline high-performance matrix resins. Demonstration of the use of these powders for preparation of both particulate and continuous fiber reinforced composite materials. Development of the first comprehensive micro-mechanics model of the interphase region between constituents. Identification of the manner by which interface and interphase parameters control "the composite effect." Development of new test methods for the small-scale characterization of composite materials. Development of scaling concepts to extend microconceptual understandings to the macroscopic level. Development of new computer simulation methods using "critical element" approaches that allow formulation of a general model for performance.

Educational Achievements

A vigorous educational program involving short courses and training courses designed to update industrial and Government scientists and engineers has been established. More than 400 scientists and engineers per year take advantage of these programs to refresh their skills or acquire new skills. A novel summer research program for undergraduate teachers, particularly those from four-year colleges and universities with large enrollments of women and minority students, has been developed and was successfully offered in 1991. The objective of the program is to introduce undergraduate teachers to key topics in the adhesive and composites fields and encourage them to introduce these topics into their undergraduate curricula. The Center runs a 12-week summer research program for undergraduates majoring in science and engineering disciplines. Admission to the program is by competitive application. It draws outstanding students from around the country to the campus each summer. The program provides an opportunity for undergraduates to experience what life would be like in graduate school and later in a career devoted to scientific research. The Center also encourages industrial and academic exchange visits.

CENTER FOR
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

NSF Directorate: MPS | Established in 1989

Center Director:	Dr. James L. Merz
Address:	Center for Quantized Electronic Structures (QUEST) University of California Santa Barbara, CA 93106
Phone:	(805) 893-8600
Fax:	(805) 893-8170
E-Mail:	merz@ece.ucsb.edu
Administrative Contact:	Debra Nash
Phone:	(805) 893-8598
E-mail:	dbn@engrhub.ucsb.edu
NSF Technical Coordinator:	Dr. Robert J. Reynik
Phone:	(202) 357-9791
E-Mail:	rreynik@nsf.gov

Research Objectives

The Center is exploring new physical phenomena that can be realized in microscopically small structures exhibiting quantum effects in one, two, and three dimensions: so-called Quantum Wells, Quantum Wires, and Quantum Dots. The controlled fabrication of individual features and of uniform arrays of these quantum structures is a major thrust of the program; novel growth and processing techniques are being developed. The physical properties displayed by these structures will be new and unexpected. Therefore, phenomena such as electron transport and optical properties will be investigated.

The device potential of these structures is expected to be great, leading to very high-speed integrated circuits and microscopically small lasers. These advances require fundamental insight into the motion and bonding of individual atoms on semiconductor surfaces. To conduct this research QUEST has assembled a multidisciplinary team of researchers with expertise in surface chemistry, materials research, electrical engineering, applied physics, and condensed matter theory, spanning five departments in the two major colleges at UCSB and recently has expanded its activities in surface chemistry and infrared physics. In addition, researchers at other universities and at national and industrial laboratories are members of QUEST. This research is closely coupled to other major research programs and centers at UCSB, such as the Institute for Theoretical Physics, the Free Electron Laser Center, and the Optoelectronics Technology Center, adding broad educational opportunities to this advanced research.

Research Achievements

Major advances have been made in the fabrication of quantum wires by several techniques. The growth of so-called "Serpentine Superlattices" on stepped substrates has been refined. In this approach the flux of incoming molecular beams is varied during crystal growth so that the semiconductor structures are S-shaped or serpentine. The resulting arrays of wires have been found, by novel polarization measurements, to be very uniform and to exhibit optical properties expected for quantum wires. Innovative lateral patterning of impurity concentrations and "stressor" regions have been produced by focused ion beam (FIB) implantations, and understanding of the role of channeling in FIB implants has greatly improved. Using electron beam lithography, stressors have been produced near the surface of samples, producing quantized effects observable at higher temperatures than have been seen before. In yet another approach, the first synthesis of compound semiconductor clusters has been achieved in Zeolite materials. Theoretical modeling has kept pace with these experiments and provided insights for future research directions.

Major advances have also been made in the difficult science of characterizing and understanding the properties of these structures. Scanning transmission microscope (STM) pictures of arsenic "dimers" (pairs of atoms) have been obtained of the GaAs surface under high vacuum. The concept and first demonstration of a "zero-gap" electron coupler has been announced, as well as the first far-infrared harmonic generation in a semiconductor heterostructure.

Educational Achievements

QUEST provides a multitiered educational program. Graduate students are immersed in a dynamic interdisciplinary environment that attracts leading researchers from the major educational and industrial institutions in the U.S. and abroad. An outgrowth of these interactions was several new graduate courses. During Winter 1990 nine quantum structure researchers from research sites such as Bell Laboratories, Bellcore, IBM, and Cornell gave lectures and consulted with students and faculty. The lectures were videotaped and are available for review. In addition, QUEST has initiated programs for younger students and their teachers. Top priority is to provide intensive laboratory experiences. Positive evaluation of a pilot internship program at QUEST laboratories for high school and undergraduate students led to increased recruiting from high schools and the Minority Education Program at UCSB. In Summer 1991 the Apprentice Researcher at QUEST program (ARQ) was initiated. Student/teacher high school teams learned about science in action through working with graduate mentors in several QUEST laboratories. An expanded version of ARQ will operate in Summer 1992.

CENTER FOR
UNIVERSITY OF MICHIGAN

NSF Directorate: MPS | Established in 1991

Center Director:	Dr. Gerard A. Mourou
Address:	IST Building, Room 1006 Ultrafast Science Laboratory 2200 Bonisteel University of Michigan Ann Arbor, MI 48109-2099
Phone:	(313) 763-4877
Fax:	(313) 763-4876
E-Mail:	mourou@eecs.umich.edu
Administrative Contact:	Autumn Craft
Phone:	(313) 763-4878
E-Mail:	autumn@eecs.umich.edu
NSF Technical Coordinator:	Dr. John Weiner
Phone:	(202) 357-7997
E-Mail:	jweiner@nsf.gov

Research Objectives

The Center concentrates on the generation of ultrashort optical pulses (in the femtosecond, i.e. 10^{-15}, domain) and their subsequent application to a diverse number of areas in basic science and applied technology. The Center's fundamental research goals are to study optics as it approaches the limits in duration (the single cycle) and ultrahigh intensity ($>10^{18}$ W/cm^2). Applications span the many fields of science, including physics, chemistry, and biology, as well as technology in electronics, photonics, and imaging.

The research can be conceptually divided into three main areas: *Ultrafast Optics*: The Center studies the generation of ultrashort optical pulses down to few femtoseconds, amplification to terawatt levels, and the nonlinear optics of propagation and manipulation. The pulse characteristics, i.e., duration, power, and wavelength, can be tailored to specific scientific or engineering applications, for example, spectroscopy, electronics, and optical comunications. *Ultrafast Science and Technology*: Ultrashort pulses are used in condensed matter physics to investigate ultrafast electronic processes in bulk and quantum confined structures. The applications extend to chemistry and biology, where the very first reactions after the absorption of a quantum of light provoke the redistribution of charges or energy in the molecule or with its surrounding in the ps-fs time scale. From an engineering standpoint, ultrashort pulses provide the most convenient way to characterize ultrafast electronic and photonic components and circuits with THz bandwidth. Optical pulse duration is also the fundamental limiting element of optical communication systems. The Center is developing techniques for exploiting

femtosecond optical pulses in applications where they can be used to provide an imaging capability through scattering media like animal tissue. *High-Field Science and Technology:* This is a newer area that has been opened as a result of the extremely high peak powers that can be generated with femtosecond optical pulses. Peak powers on the order of a terawatt can be generated that correspond to field strengths three orders of magnitude above the atomic field strength. The laser-matter interaction at this intensity level will be studied and may lead to fundamental discoveries and applications in the areas of X-ray lasers, nonlinear optics, thermonuclear fusion, and nonlinear quantum electrodynamics.

Research Achievements

Ultrafast Optics: The Center has developed a new class of amplified laser systems based on Ti:sapphire as the gain medium. These systems exploit the concept of chirped pulse amplification and, as a result, have increased the average power generated from these systems to over one Watt. One system produces 1-mJ level pulses at a 1-kHz repetition rate, while another produces microjoule level pulses at hundreds of kHz. These lasers have immediate applications as revolutionary new spectroscopic tools, as well as being a source for high-field studies available to other scientists in their own laboratories. A new femtosecond holographic technique has been developed that enables researchers to look through human tissue with light. This has significant medical applications. *Ultrafast Technology:* A high-sensitivity, 350 GHz optical detector based on LT GaAs, which also forms the basis for a 300 GHz optical waveform analyzer, has been developed. The one THz external electro-optic sampling technique has been adapted for use as a 100 GHz network analyzer of millimeter wave electronic devices. Photoconductive switching has also been implemented in antenna structures to provide for a THz beam spectroscopy system, as well as the production of picosecond duration, kilovolt amplitude electrical pulses.

Educational Achievements

The Center's education and outreach effort includes pre-college, under-graduate, and graduate activities. Emphasis is placed upon attracting more women and underrepresented minorities to careers in science and technology. The Center has initiated a Summer Science for Girls, a two-week residential program for middle school girls between the ages of 13 and 14. The girls work on a variety of projects ranging from holography to the measurement of the speed of light. The Center also has established an after-school activity for high school students in which they perform experiments related to their class studies using Center equipment not normally available at their school. A ten-week summer research program is designed to encourage undergraduate students to pursue graduate study. The Center also provides a number of fellowships and research assistantships for graduate students.

CENTER FOR
UNIVERSITY OF CALIFORNIA, BERKELEY

NSF Directorate: MPS | Established in 1989

Center Director:	Dr. Bernard Sadoulet
Address:	Center for Particle Astrophysics 301 Le Conte Hall University of California Berkeley, CA 94720
Phone:	(510) 642-4705
Fax:	(510) 642-1756
E-Mail:	sadoulet@lbl.gov
Administrative Contact:	Ann Fitzgerald
Phone:	(510) 642-4705/ 7570
E-Mail:	fitzgerald@lbl.gov
NSF Technical Coordinator:	Dr. Ben Snavely
Phone:	(202) 357-9793
E-Mail:	bsnavely@nsf.gov

Research Objectives

More than 90 percent of the mass in the universe is invisible and detectable only through its gravitational effects on objects that radiate light. Despite its fundamental role, the nature of this dark matter is unknown. University of California (UC), Berkeley, researchers collaborate with scientists from UC (Irvine, Santa Barbara, and Santa Cruz), San Francisco State University, Stanford University, Brown University, Temple University, the Lawrence Berkeley Laboratory, the Lawrence Livermore Laboratory, and five foreign groups and pursue three lines of experimental attack:

- Elucidate the nature of dark matter by attempting to detect it in the form of condensed astrophysical objects, by gravitational lensing, or in the form of particles, by sensing their interactions in cryogenic detectors of unprecedented sensitivity.
- Study the diffuse radiation from the early universe, especially the temperature isotropy of the 2.7K cosmic microwave background.
- Study the geometry of the universe through the measurement of the luminosity of supernovae at cosmological distance and the evolution of the large-scale structure of galaxies at early times. The latter program is a new initiative using the 10m Keck telescope.

This effort is fundamentally multidisciplinary and requires the development of linkages not only between many subfields of astronomy but also with particle, nuclear, and condensed matter physics. The advanced sensor technologies (cryogenic particle detectors, large CCD cameras and advanced optical and RF techniques) developed in the

Center will be useful in other scientific areas and eventually will be transferable to industry.

Research Achievements

The search for Weakly Interacting Massive Particles that may constitute the dark matter relies on a novel technology where both the phonons and the ionization liberated by an interaction are registered at milliKelvin temperatures. With a 60 gram detector, both quantities can be measured with an accuracy sufficient for a practical search, and experimentally it can be shown that the nuclear recoils expected from such dark matter particles from the background of electron recoils generated by radioactivity can be separated. This leads to a great increase of sensitivity, which justifies implementation of a pilot experiment in an underground facility at Stanford University. In another program, measurements of the isotropy of the cosmic microwave background have been made during three high-altitude balloon flights. The third flight obtained the most sensitive measurements ever made of the isotropy of the background at angular scales of 0.5 degrees. Ultimately, sensors of greater sensitivity will be used. New detectors operated at l00 mK should provide three times more sensitivity for a flight planned for 1992.

A search for Massive Compact Halo Objects, a leading candidate for baryonic dark matter, is being implemented at Mount Stromlo in Australia. For that purpose one of the largest CCD cameras used in astronomy ($2x4x(2048)^2$ pixels) has been built. Also, a promising method of using the polar ice in Antarctica for neutrino detection was successfully tested in the winter of 1991-92, and a more complete implementation is being prepared for next winter.

Educational Achievements

The question of the origin of the universe, as well as astronomy and particle physics, fascinates the general public. The Center is capitalizing on this fascination to benefit education, improve scientific literacy among the general public, and to attract larger numbers of students to science. To contribute to the development of a more diverse culture in science, the Center is engaged in a two and one-half year experimental program aimed at changing the cultural climate from "chilly" to one that is more nurturing and productive. This program is part of the Center's initiative to attract and keep bright young scientists, particularly women and underrepresented minorities, in the field. The Center is also engaged in projects aimed at improving science education at the high school, undergraduate, and graduate levels.

About 35 undergraduates, 60 graduate students, and 14 postdoctorals are involved in the Center's programs. Twenty-five undergraduates, including nine women and seven minorities, have participated in the Center's Outreach Program. New approaches to science education, such as the use of remote on-line telescopes in high school classrooms and the development of a multi-media planetarium show on cosmology, are being developed.

CENTER FOR NORTHWESTERN UNIVERSITY

NSF Directorate: MPS | Established in 1989

Center Director:	Dr. Surendra P. Shah
Address:	Center for ACBM Northwestern University The Technological Institute 2145 Sheridan Road, Room A130 Evanston, IL 60208-4400
Phone:	(708) 491-3858
Fax:	(708) 467-1078
E-Mail:	spshah@casbah.acns.nwu.edu
Administrative Contact:	Mary Lynne Williams
Phone:	(708) 491-8569
E-Mail:	ml_williams@plato.nwu.edu
NSF Technical Coordinator:	Dr. Robert J. Reynik
Phone:	(202) 357-9791
E-Mail:	rreynik@nsf.gov

Research Objectives

Researchers from Northwestern University, the University of Illinois, the University of Michigan, Purdue University, and the National Institute of Standards and Technology are investigating properties and processes of cements and will establish comprehensive principles for designing cement-containing materials with improved properties.

Research is being conducted on the chemistry and physics of cementitious materials as well as on processing science, microstructural analysis, material properties, fracture toughness, and fiber reinforcement. The goal of the Center is to create an interdisciplinary materials science approach to the understanding of how high-performance cement-based materials can be created at the atomic, molecular, and micron level. This approach synthesizes efforts in micromechanics, materials engineering, rheology, interface chemistry, and toughening mechanisms of fiber reinforcement. Such an integrated approach will enable a more efficient use of cement-based materials for rehabilitation of infrastructure, manufactured building components, waste-disposal systems, and heat and abrasion resistant parts for tools and electronic devices.

Research Achievements

- The pore structure of concrete allows corrosive fluids to enter bridge decks and corrode reinforcing steel. Improvement is possible by controlling the way cementitious particles form the glue that binds sand and stone particles. The Center has produced a dense particle-packed system that yields cement with a compressive strength of 100,000 psi, which is 25 times the strength of conventional concrete.
- The Center has demonstrated that fracture strength can be dramatically increased by the addition of small diameter, uniformly dispersed fibers. Tough, flexible, fiber-reinforced concrete has been created that is 100 times more flexible than convention concrete. In the future this experimental material may enable bridges, roads, and buildings to flex rather than break during earthquakes.
- To accelerate the curing process, the Center is examining microwave energy. Microwaves can be used to accelerate strength development.

To understand how and why the global properties of cementitious systems are affected by porosity or the presence of polymers or fibers, several innovative experimental techniques have been employed. They include: nuclear magnetic resonance, impedance spectroscopy, digital image analysis, acoustic emission source location, and laser holography. These techniques may find applications as nondestructive testing methods to monitor the condition of buildings, bridges, and roadways.

Educational Achievements

Since its inception the total number of students in the graduate program in the four ACBM academic institutions has increased six-fold; the number of female students enrolled and native born U.S. citizens participating, three-fold. Interdisciplinary interactions are fostered by an annual graduate student assembly and by joint thesis advising between disciplines and institutions. The Center co-sponsors an annual Computer Modeling Workshop at the National Institute of Standards and Technology to stimulate student and faculty researchers, as well as industrial affiliate scientists, to participate in theory, modeling, and simulation of behavior of cementitious materials.

A special one-week summer workshop entitled "Materials Technology" is challenging high school physics and chemistry teachers to incorporate materials concepts in their courses and help their students make better informed academic and career choices. One segment of the workshop is on concrete and includes an interactive lecture, a demonstration laboratory, and hands-on experiments. Also an Education Committee has been appointed to build support for educational outreach plans in the areas of interinstitutional courses, faculty workshop development, future computer modeling, course expansion to the undergraduate level, and minority and women recruitment.

CENTER FOR
UNIVERSITY OF TEXAS, AUSTIN

NSF Directorate: MPS | Established in 1991

Center Director:	Dr. John M. White
Address:	Department of Chemistry University of Texas Austin, TX 78712-1167
Phone:	(512) 471-9462
Fax:	(512) 471-9495
E-Mail:	cmab710@hermes.chpc.utexas.edu
Administrative Contact:	Pam Cook
Phone:	(512) 471-9462
E-Mail:	cmab710@hermes.chpc.utexas.edu
NSF Technical Coordinator:	Dr. John B. Hunt
Phone:	(202) 357-7947
E-Mail:	jbhunt@nsf.gov

Research Objectives

The research is organized into two thrust areas—compound semiconductors and silicon-based materials. Within each thrust area there is strong coupling between chemists, engineers, and physicists. In addition to materials-related issues, other basic scientific issues link the two thrust areas, such as the need for understanding of surface chemical processes that control thin film nucleation and growth. The research will be conducted in cooperation with Sandia National Laboratory, Texas Instruments, Inc., Motorola, Inc., and the University of Texas, El Paso.

In the compound semiconductor thrust, the research will consist of three interrelated activities: synthesis, purification, and surface reactivity measure-ments of novel precursors containing the group III and group V elements in a single molecule that have low toxicity and are suitable for advanced organometallic chemical vapor deposition (OMCVD) and chemical beam epitaxy (CBE); measurement and modeling, on a femtosecond time scale, of optically generated hot-charge carriers; and investigation of the parameters that control the growth of device-quality thin film crystals of III-V semiconduc-tors by molecular beam epitaxy (MBE), OMCVD, and CBE. The work on silicon-based materials consists of four closely coupled activities: synthesis of alternative chemical precursors and the optimization of deposition reactions for particular materials growth techniques; detailed surface and interface studies of ultra-thin materials and heterostructures; application of a complementary set of low thermal energy materials growth techniques (rapid thermal processing CVD, remote plasma CVD, photo-enhanced deposition, and low-pressure CVD for the development of viable three-dimensional structures and ultra-small silicon-based heterostructures; and analysis and modeling of Si-based heterostructure and charge transport behavior.

Research Achievements

The Center has aggressively pursued research on Column IV semiconductors and III-V compound semiconductors. Early accomplishments include the preparation and purification of two new single-source precursors, the growth of a single crystal film of GaAs from one of the precursors, and the design and construction of a surface analysis instrument for examining the thin film growth of these and other III-V precursors. Using RPCVD, Si and Ge epitaxy have been established at temperatures as low as 150 degrees centigrade, and Si-Ge alloy characteristics have been measured using femtosecond ellipsometry. In collaboration with scientists from Sandia National Laboratory, the detailed thermal and photon-driven surface chemistry of AsH_3 and $Ga(CH_3)_3$ on GaAs(100) have been investigated. The Center has "seeded" the exploration of porous silicon, a potentially important optoelectronic material that has recently captured the attention of electrical engineers. For his substantial contribution to this project, Carl Matthews, an undergraduate, was named by *USA TODAY* to the All-USA College Academic Second Team.

Educational Achievements

The Center has initiated an undergraduate research program, weekly student seminars by graduate students and undergraduates, a summer program for minority undergraduates, a government/academic/industrial seminar series, and reciprocal research exchanges with Sandia National Laboratory staff. The graduate-level course in the synthesis, growth, and analysis of electronic materials drew 24 students from natural science and engineering. In the summer the Center will host a day camp with a broad science and technology focus for minority middle school children. The Center is also in the process of adopting a class of 21 students at Zavala Elementary School in Austin, Texas. Center participants will visit this fifth grade class every two weeks during the 1992-93 school year. In addition the Center will host class visits to the University of Texas, assist the teacher in incorporating science more fully into the curriculum, provide demonstrations and hands-on laboratory activities that illustrate key scientific concepts, and establish one-on-one relationships with these almost exclusively minority students.

CENTER FOR
UNIVERSITY OF ROCHESTER

NSF Directorate: MPS | Established in 1989

Center Director:	Dr. David G. Whitten
Address:	Department of Chemistry University of Rochester Hutchison Hall Rochester, NY 14627
Phone:	(716) 275-8286
Fax:	(716) 473-6889
E-Mail:	stc@chem.chem.rochester.edu
Administrative Contact:	Debbie Shannon
Phone:	(716) 275-8286
E-Mail:	stc@chem.chem.rochester.edu
NSF Technical Coordinator:	Dr. John B. Hunt
Phone:	(202) 357-7947
E-Mail:	jbhunt@nsf.gov

Research Objectives

The University of Rochester, the Eastman Kodak Company, and the Xerox Corporation are collaboratively investigating how light drives a broad range of chemical reactions, including several that are technologically important. All these reactions depend on the light-activated transfer of charge (electrons) from molecule to molecule, a process that can be manipulated to create desirable electronic and chemical effects in various states of matter. The objectives of the Center are to understand:

- What factors control the fundamental rates and efficiencies of electron transfer, charge separation, and charge transport?
- How can these factors be controlled and varied to obtain new chemistry and useful reaction products?
- How can materials and devices be developed for photochemically based technology?

To facilitate this scientific work, the Center is: developing new modes of collaborative research involving academic and industrial laboratories, including industry-industry interactions; establishing new instrumental capabilities for the study of photoinduced charge transfer; and organizing a broad range of educational and outreach programs.

Research Achievements

A unique model for academic-industrial collaborative research has been established at the Center. Within this framework, scientists from Xerox, Kodak, and the University of Rochester are collaborating on 15 projects spanning the broad range of fundamental investigations in charge transfer chemistry. A three-way patent agreement is a straightforward invitation to Center members to cooperate to solve problems that have long been recognized in the individual research laboratories. Significant results already obtained include:

- Identification of vibrational modes promoting electron transfer;
- Discovery of new chemical reactions of cation radicals;
- Development of acceptors for electron transfer in non-polar media;
- Discovery of a novel electron transfer-spin inversion mechanism in exciplexes;
- Discovery of superexchange electron transfer in Langmuir-Blodgett films;
- Observation that mutagenesis affects redox protein binding, but not necessarily redox rates;
- Measurement of 40-fs dynamics for electron transfer at semiconductor surfaces;
- Discovery that free exciton emission dominates in AgBr nanocrystals;
- Calculation of rates of charge transport in polyacteylene;
- Development of a theory of superradiance for J-aggregates; and
- Development of new photoconductive polymers with high industrial potential.

Educational Achievements

The Center provides a unique set of learning and teaching opportunities in a collaborative academic-industrial setting. Programs and activities include:

- Postdoctoral, graduate, and undergraduate research programs involving academic-industrial collaboration;
- A Summer Research Program for High School and Community College Teachers;
- Core, Special Topics, and Short Courses, taught by academic and industrial scientists;
- A Center Visiting Speaker Program coordinated with the industrial laboratories;
- An annual International Symposium on Photoinduced Charge Transfer (30% of the participants are students);
- A Visiting Scientist Program for short- and long-term research visits by faculty and scientists from other institutions;

- Development of a low-cost Scanning Tunneling Microscope and associated experiments and manuals by Center and Xerox scientists for use in high schools and colleges.

.I. TECHNOLOGY TRANSFER

Technology transfer, *the two-way flow of knowledge and know-how between organizations involved in the development and use of new technology*, is a significant component of the STCs. This exchange of knowledge (technology transfer) occurs in a variety of ways—person to person contact as well as the development of new research tools, new software, patents, and new products. For example, industrial scientists are engaged in collaborative research with the Centers, serve in the management structure of the STCs, serve on the External Advisory Committees for the STCs as well as the industrial advisory boards, and participate in the Centers' industrial affiliates groups. Industry provides resources to the Centers in the form of: funds for research and support of students, personnel, loans and donations of equipment, access to specialized industrial facilities, and employment for postdoctorates and graduate students. Cross-training occurs. Industrial scientists participate in workshops, seminars, and training sessions organized by the Centers. They may also participate in teaching academic courses. Industrial participation in each of the STCs is listed below followed by a listing of the new technology developed by each STC since its inception. Not only is new technology being developed, but also new companies are being spawned. For example, Medox Research (MXR) and Picotronix have been created based on the research underway at the Center for Ultrafast Optical Science. MXR is concentrating on the development of compact, femtosecond laser sources, and Piccotronix is focusing on optoelectronic devices based on the new high-speed photoconductive materials.

STC Industrial and National Laboratory Participants and New STC Technology

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Biological Timing,
University of Virginia **2**

Industrial Liaison: Gene Block (804) 982-5480

Industrial Participants

Promega Corporation

New STC Technology

Research Tools

NeuroDynamix: Integrated Computer Model that Simulates the Dynamic Properties of Individual Neurons & Interactions Between Neurons

Engineering Plants for Resistance Against Pathogens,
University of California, Davis **4**

Industrial Liaison**:** George Bruening (916) 752-3474

Industrial Participants

Beatrice/Hunt-Wesson	California Tomato Board
Calgene, Inc.	CIBA-GEIGY (Research Triangle, NC)
California League of Food Processors	Ragu Foods

Molecular Biotechnology, *California Institute of Technology* **6**

Industrial Liaison: Leroy Hood (818) 397-2765

Industrial Participants

Affymax, Inc	Lawrence Berkeley Lab.
Applied Biosystems, Inc.	Lawrence Livermore Lab.
Beckman Instrument Company	Los Alamos National Lab.
Bio-Rad	Molecular Biology Resources
Digital Equipment Corporation	Molecular Dynamics
Daniel H. Wagner Associates	Monsanto
Dionex	Protein Design Labs.
Dynatech	Tropix
Finnigan MAT	TRW
Hewlett-Packard	Upjohn
Jet Propulsion Laboratory	Zymark

New STC Technology

Patent Application

Thermostable Ligase Mediated DNA Amplification

Software

Biological Information Signal Processor (BISP) Chip

Research Tools

2D Gel Electrophoresis Apparatus	Protein Sequenator
Protein Sequencer	

Magnetic Resonance Technology for Basic Biological Research, *University of Illinois* **8**

Industrial Liaison: Paul Lauterbur (217) 244-0600

Industrial Participants

Ability Engineering Technology, Inc.
General Electric Corporate R&D
Houston Advanced Res. Center/Texas Accelerator Center
IBM, T. J. Watson Res. Center
Lawrence Berkeley Laboratory
Salutar, Inc.
Surrey Medical Imaging Systems, Ltd.

New STC Technology

Invention Disclosures

Electronically Switched, Multi-Mode, Easy to Wrap Gradient Coil Assembly Made with Ribbon Cables for NMR Imaging
Method for Efficient MRI Using a Generalized Series Model

Research Tools

NMR Surface Microscope
Electrode Chamber for NMR
Apparatus for Simultnaeous NMR, Mechanical, and Electrical Measurements on Isolated Muscle
True-Current Gradient Power Supply
Rapid-Switching NMR Gradient Coils
Method for Magnetic Labelling of Cells
Integrator/Pick-up Coil for Direct Measurement of Time Varying Magnetic Field Gradients

Software

4D Projection Reconstruction Imaging Algorithm
Automated Image Segmentation with a Fuzzy Logic Algorithm
Viewit: Software for Multidimensional Image Processing, Reconstruction, and Visualization
Programs for Boundary-Constrained Localized MR Spectroscopy
Efficient Algorithm for Half-Fourier Image Reconstruction
Integrated 3D Display of MR Images and Spectra of Brain
Linear Prediction Algorithm for Phase Corrections of MR Spectroscopic Imaging Data
Diffusion Simulation Algorithm

Light Microscope Imaging and Biotechnology, *Carnegie Mellon University* **10**

Industrial Liaison: Daniel Farkas (412) 268-3456

Industrial Participants

Biological Detection Systems, Inc.
Carl Zeiss
Kodak
Lawrence Livermore Lab.
Photometrics, Ltd.

New STC Technology

Invention Disclosures

Methods for Producing Photoactivatable Macromolecules

Research Tools

Multimode Microscope
New Fluorescent Labeling Reagents
Personal Cytometer

Microbial Ecology,
Michigan State University **12**

Industrial Liaison: Larry Forney (517) 353-9021

Industrial Participants

Ambis
Dow Chemical
Eli Lilly
General Electric
Meridian Instruments
Monsanto
Procter & Gamble
Solid Waste Composting Council
Upjohn

New STC Technology

Invention Disclosures

Use of Ozone for the Remediation of Soils and Aquifers Contaminated with Toxic Chemicals
Electrolysis Cell for Hazardous Waste Treatment
Diffusion Gradient Chamber
N-Acetylglutamate as an Agent for Promoting Root Hair Branching and Nodule Initiation in the *Rhizobium*-Clover Symbiosis
Use of Tandem Mass Spectrometric Techniques for the Detection and Identification of Microorganisms
Microbial Degradation of Methyl Tert-Butyl Ether (MTBE)
Biodetector for Aromatic Pollutants

Patent Applications

Increased PCE Dechlorination by Induction of Chlorobenzoate Dechlorination Activity
A Plant Cryoprotective Protein

Patent

Bioproduction of Cyclic Hydroxides

Research Tools

Gradient Chamber
Laser Tweezer

Research in Cognitive Science,
University of Pennsylvania **14**

Industrial Liaison: Aravind K. Joshi (215) 898-8540

Industrial Participants

AT&T Bell Laboratories
BBN Systems & Technology Corp.
Bellcore
General Electric
General Motors
Hewlett Packard Laboratories
IBM, T. J. Watson Res. Center
Siemens Corporation
Unisys Corporation

New STC Technology

Research Tools

XTAG (Graphic Interface for TAG Grammar Development, Together with a Parser and Grammar)

ACL-DCI CD-ROM 1 (Collection of Text and Lexicon for NL Research Distributed Through ACL)

Software

Jack (Programming Language and Collection of Tools for Articulated Figure Animation and Human Factor Evaluation)

xv (X11 Image Display Program; Part of the Picture Manipulation Library)

Discrete Mathematics and Theoretical Computer Science, *Rutgers University* **16**

Industrial Liaison: Daniel Gorenstein (908) 932-5928

Industrial Participants

AT&T Bell Laboratories
Bellcore
NEC
Sun Corporation

Computer Graphics and Scientific Visualization, *University of Utah* **18**

Industrial Liaison: Donald Greenberg (607) 255-7444

Industrial Participants

Digital Equipment Corporation
Hewlett-Packard
IBM

Research on Parallel Computation, *Rice University* **20**

Industrial Liaison: Ann Redelfs (713) 285-5188

Industrial Participants

Aerospace Corporation
Alliant Computer Corporation
ARCO
Bolt, Beranik, and Newman
Convex Computer Corporation
Cray Research
Digital Equipment Corporation
IBM
Intel Corporation
Mobile Research & Development Corporation
Nektonics Research, Inc.
NCUBE
Shell
Thinking Machines Corp.
United Technologies
Western Atlas International

New STC Technology

Research Tools

Parallel C++ Compiler and Libraries (Prototype)

Software

PCN High-Level Parallel Programming System
Semi-Coarsening Multigrid Code for Hypercube
Parallel Version of MM4 Mesoscale Model
Fortran 77D Compiler (Prototype)
Optimal Oil Well Placement (Design Stage)
ADIFOR (Automatic Differentiation Prototype)
Parallel Shallow Water Equation Solvers
Large-Scale Symmetric Eigenvalue Algorithm
Parallel Direct Search Method Algorithm
Parallel Version of UTChem
Mixed Finite Element Domain Decomposition Algorithm
Parallel Spectral Element Navier-Stokes Solver
PIERS-Oil Recovery Simulator
Airline Scheduling Simplex Algorithm
ParaScope (Improved)
Semi-Coarsening Domain Decomposition Code
Parallel Version of Taylor-Couette Flows
Parallel Version of Computational Fluid Dynamics Code Nekton
Parallel Version of CAPS Storm Model

Southern California Earthquake Center, *University of Southern California* **22**

Industrial Liaison: Geoffrey Martin (213) 740-5830

Clouds, Chemistry, and Climate, *University of Chicago* **24**

Industrial Liaison: David L. Cutchin (619) 534-8815

Industrial Participants

Argonne National Laboratory - Environmental Research Division
National Center for Atmospheric Research
Ford Motor Company - Research Division

Astrophysical Research in Antarctica, *University of Chicago* **26**

Industrial Liaison: Raymond Willis (414) 245-5555

Industrial Participants

AT&T Bell Laboratories
Rockwell International Corp.

Analysis and Prediction of Storms, *University of Oklahoma* **28**

Industrial Liaison: Douglas Lilly (405) 325-3041

Industrial Participants

DEC

New STC Technology

Software

ARPS v 2.5
RDSS Modification for UDF/Nexrad
GRIB, GKS Interface, UDF Readers
Steller Interface for ARPS

High-Pressure Research,
SUNY, Stony Brook **30**

Industrial Liaison: John Parise (516) 632-8241

Industrial Participants

Argonne National Laboratory
Brookhaven National Laboratory
DuPont Central Research & Develop.
Exxon
General Electric Superabrasives
IBM, T. J. Watson Res. Center
Los Alamos National Lab.

Advanced Liquid Crystalline Optical Materials,
Kent State University **32**

Industrial Liaison: John West (216) 672-2654

Industrial Participants

AT&T Bell Laboratories
BFGoodrich Aerospace Display Systems
W. H. Brady Company
DJK Corp. of America, Inc.
Edison Polymer Innovation Corp.
F. Hoffmann-La Roche Ltd.
Hughes Research Laboratories
Polaroid Corporation
Raychem Corporation
Reveo, Inc.
Rockwell International Corp.
Vari-Lite, Inc.

(Industrial Users of ALCOM Resource Facility)

AMETEK
BFGoodrich Aerospace Display Systems
Crystaloid
Hughes Research Laboratories
IMAX
Los Alamos National Laboratory
LXD
Magnascreen
Martin Marietta
McDonnell Douglas
Naval Coastal Systems
Rockwell International Corp.
Stereographics
Tektronix
Vari-Lite, Inc.
Xerox Corporation

New STC Technology

Invention Disclosures

Gel Monomers for High Modulating Devices

Multistable Display Material for Gray Scale

Research Tools

Reflective Color Display

Paste of Liquid Crystal Dispersed Polymers for Electro-optical Devices

Patent Application

Liquid Crystal Light Modulating Device

Superconductivity,
University of Illinois **34**

Industrial Liaison: Christine Platt (217) 333-1744

Industrial Participants

American Superconductor Corporation
Argonne National Laboratory
AT&T
Bell Communications Research
Conductus
DuPont
Emcore
General Electric
Hewlett-Packard
IBM
Illinois Superconductor Corp.
Superconductor Technologies
TRW
Westinghouse

New STC Technology

Invention Disclosures

Low Temperature Deposition of Diamond Films for Optical Coatings
Enhancement of Mechanical Properties of 123 by Addition of BaSnO3
Diffusion Modification of Grain Boundaries of 123 for Improved Superconductor
Stabilized Tetragonal 123 as Insulator for Superconducting 123
Pulsed Organo-metallic Beam Epitaxy of Complex Oxide Films
Pulsed Laser Deposition of BKBO Films in a Reducing Atmosphere
Faced Magnetron Sputtering Gun
New Insulating Substrate for 123
Low Pressure Sintering of 123 Superconductor Containing High Organic Loading
Improved Channeling of Magnetic Field by Superconductor
Annealing Process for Bi-Sr-Ca-Cu-O Superconductors
Direct Recoil/Ion Scattering Spectrometer

Patents

Helium Dilution Refrigeration System
Superconducting Transmission Line Particle Detector
In Situ Analyzer of Surface Composition of Growing Films
Method of Forming Superconducting Materials
Superconducting Transmission Line Particle Detector
Apparatus to Uniformize Sputtered Films
Computer-Controlled Sputter-Deposition System for Multi-Component Thin Films

Filed CIP

Method of Forming Superconducting Materials

Computation and Visualization of Geometric Structures,
University of Minnesota **36**

Industrial Liaison: Albert Marden (612) 624-5851

Industrial Participants

AT&T Bell Laboratories
IBM

New STC Technology

Software

Linktool
Color Printer Tools
Sun XGL Viewer
Mathematica Graphics to MinneView Converter
Getmatlist
Rmovie
Image Compositor
Hyperbolic Viewer
MinneView 0.1 Release
OOGL Version 1.0

High-Performance Polymeric Adhesives and Composites,
Virginia Polytechnic Institute and State University **38**

Industrial Liaison: James McGrath (703) 231-5976

Industrial Participants

Amoco Chemical
Air Products
Akzo Americas
Allied-Signal
Ashland Chemicals
Boeing
Dow Chemical
DuPont
Eastman Kodak
Exxon
Ethyl Corporation
Hercules Inc.
Hoechst-Celanese
IBM
Lord Corporation
MMM
Monsanto
Phillips Petroleum
Shell Corporation

New STC Technology

Invention Disclosures

Oxygen Plasma Resistant Polymeric Film and Fiber Forming Phenyl Phosphine Oxide Macromolecules
Process for Preparing Fine Polymeric Powders
Homogeneous and Micro-Heterogeneous Polymer-Metal Complexes Based on Phosphine Oxide Containing Polymers

Patent Applications

Purification and Recovery of Xylan Polysaccharides
Isolation of Xylan-Rich Oligosaccharides from Water-Soluble Steam-Exploded Biomass
Alkylene Oxide Esters of Lignin Sn^{-1} Fonic Acid
Lignocellulosic Beads - Preparation, Activation and Characterization

Patents

Lightweight, Permanently Attachable Sensors for Non-Destructive Evaluation
Method of Producing Prepolymers from Hydroxyalkyl Lignin Derivatives

Research Tools

High-Velocity Impact Device
Vacuum Oven Interferometric Measure
Infrared Microscope System
Moire Interferometer High-Temperature Applicator
Improved Data Acquisition System
Peninsula Blister Test System
Resin Pot

Software

Random Node Mesh Generator
MRLife 6 - Performance Simulation Code
Hybrid Analysis Package
Computer Simulation-Visualization Interfacial Structure

Quantized Electronic Structures,
University of California, Santa Barbara **40**

Industrial Liaison: James Merz (805) 893-8600

Industrial Participants

AT&T Bell Laboratories
Bellcore
Boeing
DuPont
Hewlett-Packard
Hughes Research Laboratories
IBM
Intevac
Jet Propulsion Laboratory
Lytel
Motorola
Rockwell International Corp.
Tektronix
TRW
Argonne National Laboratory
Brookhaven National Lab.
Los Alamos National Lab.
Sandia National Laboratory

New STC Technology

Invention Disclosures

Monte Carlo Simulations
Method of Producing Nanometer-Pitch Ridged Surface
Self-Consistent Poisson-Schrodinger Solver
Femtosecond Measurement System

Patent Applications

Method of Producing Nanometer-Pitch Ridged Surfaces
Serpentine Superlattice Patent
Quantum Charge Pump
Multi-emitter Parallel Resonant Tunnel Diodes
Focused Ion Beam Modulation Doping

Research Tools

High Vacuum Vapor Deposition System
In Situ Processing Machine
MOCVD System
Photo Elastic Modulator
Sample Transfer Chamber
Measurement System for Far-Infrared Harmonics
Scanning Tunneling Electron Microscope
Cryogenic Stripline and Horn
MEE Regrown Quantum Wire Laser
Low Magnetic Field Sample Heater
Synthesis Apparatus
Machine: Study Chem. of GaAs/GaA1As

Software

Self-Consistent 2D Poisson-Schrodinger Solver
2D Poisson-Schrodinger Simulator

Ultrafast Optical Science,
University of Michigan **42**

Industrial Liaison: Gerard Mourou (313) 763-4877

Industrial Participants

Allied Signal Corporation
APA Optics
Clark Instruments
Coherent, Inc.
ERIM
Fujitsu Laboratories Ltd.
General Electric
Jobin-Yvon
Kodak
Los Alamos National Laboratory
Rome AFB
Laser Photonics, Inc.
Medox Electro-Optic
Medox Research
Picotronix
Quantel
Quantronix
Siemens
Spire
Thompson-CSF
MIT Lincoln Laboratories

New STC Technology

Patent Application

Amplification of Ultrashort Pulses with Nd:Glass Amplifiers Pumped by Alexandrite Free-Running Laser

Research Tools

High Repetition Rate Regenerative Amplifier
1 kHz, 1 mJ, 100 fs, Ti:sapphire Regenerative Amplifier Laser System
350 GHz Gallium Arsenide High-Sensitivity Optical Detector
300 GHz Optical Waveform Analyzer
100 GHz Electro-optic Network Analyzer for Electronic Devices
100 fs, 1 J, Terawatt Laser System
Generation of Picosecond Duration, Kilovolt Level Pulses
250 kHz, 1 uJ, 100 fs, Ti:sapphire Regenerative Amplifier Laser System
Femtosecond Holographic Imaging Through Tissue
THz Beam Spectroscopy System
1 THz Electro-optic Integrated Circuit Internal Node Probe
100 GHz Electro-optic Waveguide Modulator

Particle Astrophysics,
University of California, Berkeley **44**

Industrial Liaison: Bernard Sadoulet (510) 642-4705

Industrial Participants

Lawrence Berkeley Laboratory
Lawrence Livermore Laboratory
Lockheed

New STC Technology

Research Tools

Large CCD Camera
Neutron Transmutation Doped Thermistors for Millimeter Wave and Particle Detection
VLSI Processor for Radio Astronomy
High-Electron Mobility Transistors
High-Pressure Xenon Projection Chamber for Hard X-ray Astronomy

Advanced Cement-Based Materials, *Northwestern University* **46**

Industrial Liaison: M. Thomas McCall (708) 491-3858

Industrial Participants

Arco Chemical Company
Ciments Francais/ESSROC Corporation
Concrete Technology Corporation
Construction Technology Laboratories
The Gillette Company
LaFarge Fondu International
MTS Systems
NMR Steelastic
U.S. Army Corps of Engineers Construction Engineering Research Laboratory
Partek
Portland Cement Association
Procter & Gamble Company
Specrete-ip, Inc.
Rhone-Poulenc, Inc.
Schlumberger Specrete-ip, Inc.
3M Corporation
USG Corporation
Westinghouse
W. R. Grace & Company

New STC Technology

Software

Cement Microstructure Modeling

Synthesis, Growth, and Analysis of Electronic Materials, *University of Texas* **48**

Industrial Liaison: John G. Ekerdt (512) 471-9462

Industrial Participants

Motorola
Sandia National Laboratory
Texas Instruments, Inc.

New STC Technology

Invention Disclosures

Heterostructure Metal Insulator Semiconductor Field Effect Transistor

Silicon Atomic Layer Epitaxy Process Based on Si_2H_6 and Remote He Plasma Bombardment

Photoinduced Charge Transfer, *University of Rochester* **50**

Industrial Liaison: Samar Farid (716) 275-8268

Industrial Participants

Eastman Kodak

Xerox Corporation

New STC Technology

Patent Application

Photoconductive Imaging Members with Ladder Polymers

Research Tools

Scanning Tunneling Microscope

Ultra-High Vacuum Apparatus

Picosecond Laser

Fast Scanning Cyclic Voltammetry

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Phone: (202) 357-9808
FAX: (202) 357-9802
Office e-mail: (**stc@nsf.gov**)

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